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THE KAOLINS OF THE DRY BRANCH REGION, GEORGIA.[1]

OTTO VEATCH.

Sedimentary kaolins are being mined extensively in central Georgia, and their present economic importance and probable future greater importance, aside from their scientific interest, makes them worth the attention of the economic geologist. The principal clay mines are located near Macon, Georgia, in what is known as the Dry Branch region. The products of the mines are shipped to potters and paper manufacturers, and are used extensively in the manufacture of white ware pottery, sanitary ware, electrical porcelain, saggers and fire clay products, and as a filler chiefly for wood pulp paper.

GEOLOGY.

The clay occurs in strata of lower Cretaceous age, the Tuscaloosa or Potomac formation, and is of sedimentary origin. The clay beds are contiguous to the Fall Line, the contact between the ancient crystalline rocks of the Piedmont Plateau and the recent Coastal Plain formations, and are often spoken of as the Fall Line clays.

In Georgia, the Tuscaloosa formation (Potomac), which bears the clays, is a narrow belt of crossbedded sand, gravel and clay which lies in contact with the crystalline rocks of the Piedmont

[1] Published by permission of the state geologist of Georgia.

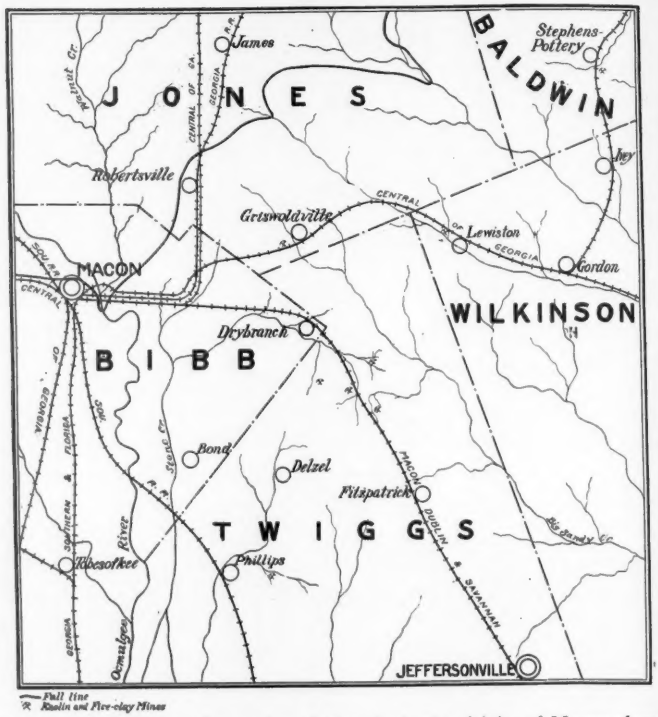


FIG. 10. Sketch-map of a portion of Georgia, in the vicinity of Macon, showing location of Clay Deposits and Fall Line.

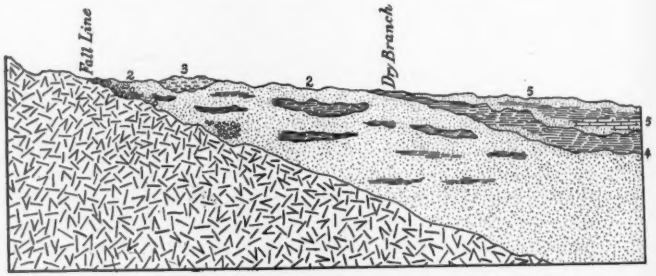


FIG. 11. Generalized Northwest-southeast section, Dry Branch region.

Plateau and extends entirely across the State in a northeast-southwest direction. It is probably of lower Cretaceous age, although it contains no fossil evidence, either plant or animal, and is correlated with the Tuscaloosa of Alabama only by stratigraphical continuity. The formation varies in thickness from 50 to 500 or 600 feet.

In the Dry Branch region, the lower part of the Tuscaloosa (Potomac) consists of clayey sand and gravel characteristically crossbedded and gray or red in color, and may be quite coarse in texture near the contact with the crystalline rocks, or, locally, may be an arkose. It contains lenticular beds of white clay, but these lenses are of small extent, vary in texture, and grade into sand abruptly. As a whole, the formation is unconsolidated. In the upper part of the formation, in the vicinity of Dry Branch, white clay beds or plastic kaolins of remarkable purity and extent occur and form the subject of this paper. These clay beds vary in thickness from 8 to 30 feet, and are unconformably overlain by sands, clays and limestones of Eocene age. The kaolins are generally very plastic, have a low air shrinkage, and in their air-dried tensile strength show 10 or 12 pounds per square inch to 100 pounds; they are white burning and show a high fire shrinkage. Their fusing points are high, lying near 3300° F. and above.

STRUCTURE OF THE CLAY DEPOSITS.

The structure of the clay is quite simple; it occurs in massive layers which represent a continuous deposition and does not show lines of stratification or lamination, such as are usually seen in clays or shales of sedimentary origin. The beds lie almost horizontal, and show no appreciable faulting or fracturing—facts of considerable importance in the mining of and prospecting for the kaolin. The beds are but little disturbed from their original positions, and only purely local movements have taken place.

Jointing is prominent; but there is no system of jointing and the joints are really cracks which seem to be due to tension caused by the shrinkage from loss of water, and partial consolidation of the clay. Slickensided surfaces are noted along the joint planes,

indicating movement of one mass of clay over another; movement as much as six inches has been noted, and much greater has probably taken place. The jointing is an economic feature, in that it facilitates the mining of the kaolin.

The tops of the kaolin beds present an irregular surface due to erosion which took place prior to the deposition of the overlying Eocene formations. The kaolin bed may show considerable variation in thickness, due to these old erosion gullies, which are now filled with red sand and impure clays of the Eocene.

THEORY OF ORIGIN AND DEPOSITION.

The white clays of the Tuscaloosa in Georgia are clearly of sedimentary origin, and were derived from the northward from the crystalline rocks of the Piedmont Plateau. The greater part of the Piedmont Plateau from which the lower Cretaceous was derived, is composed of granites, gneisses and feldspathic schists, cut by basic trap dikes and diorite intrusions. The basic dikes and basic diorite intrusions form only a small part of the whole area and the latter are themselves cut by granite intrusions and pegmatites. The region, then, is on the whole a highly feldspathic one, and the weathered residue of its rocks is consequently highly argillaceous. The red soil, so characteristic of the Piedmont Plateau, is, after all, only a surface phenomenon. With the exception of certain small areas which are underlain entirely by basic eruptives, it rests on gray or white decomposed and disintegrated rocks. The feldspars and other aluminous minerals of these rocks have altered to kaolinite or allied minerals.

The greater part of the Piedmont region has been a land surface since the close of Cambrian time, and the amount of weathering of its rocks, effected during the great intervals of time represented by the Silurian and Carboniferous epochs, was perhaps as great during the Cretaceous period as at present. Subsequent to the deposition of the Carboniferous strata and just before the beginning of the Cretaceous, the Piedmont region suffered a great uplift with a tilting to the southeast. The result of this movement was a rejuvenation of the drainage, the direction of which was essentially the same as at present; and the streams

set rapidly to work carrying the weathered residue down to the Cretaceous sea.

The steepness of the slope of the ancient Piedmont region may in a measure be inferred from the steepness of the crystalline floor now overlain by Coastal Plain sediments. This floor slopes southeastward 50 to 75 feet per mile and the altitude of the land during the Cretaceous must have been much greater than at present. As a result of steep gradient, streams were very active, perhaps torrential in character, a fact which is indicated by the frequent coarseness of sediment and evidences of rapid deposition. The deeply weathered material of granites and gneisses in the main was picked up and dumped on the shore of the Cretaceous ocean as alluvial fans or at the mouths of streams as deltas, the delta of one stream mingling with and overlapping that of another. An enormous amount of sediment rapidly dumped at the mouths of streams resulted (1) in the formation of sand flats; (2) in the formation of fresh water delta lakes; and (3) possibly in the enclosing of areas of sea-water by sand barriers, which were at once freshened by the inflow from land streams. In the deeper and quieter waters of off-shore lakes and sounds, the fine clay particles were deposited in non-persistent and lenticular beds of pure white clay, while in the shallower water under conditions of shifting currents, the crossbedded sands and occasionally beds of pebbles were laid down. Conditions, however, did not remain uniform for any great length of time. One set of barrier lakes formed, were filled up and other lakes formed. Layers of sand and clay were laid down, subsequently subjected to the action of currents, partly eroded and redeposited. The evidence of this is the abundance of clay pellets, pebbles and large angular chunks of white clay mingled with sand and superimposed unconformably upon white clay beds.

The entire absence of marine conditions supports this theory. No marine shells or any animal remains whatever have been found in the Tuscaloosa in Georgia. Also, very strangely, there is so far as is known at present, an absence of plant remains in

the Tuscaloosa. This fact is difficult of explanation, since clays are favorable for the preservation of plants and since an abundant flora has been found in the other States in formations which are regarded as synchronous with the Tuscaloosa in Georgia; and when it is known that the beds of the upper Cretaceous which closely succeeded it in deposition are lignitic and contain abundant plant remains. The upper Cretaceous directly overlies the Tuscaloosa and succeeded it in deposition without any interval during which there was uplift or land period. In the lower Cretaceous there are no lime nodules or even calcareous layers of any description. No traces of sulphides (pyrites) or sulphates have been observed either in the sand or clay; manganese nodules which indicate marine conditions, are not found as an original constituent in the Tuscaloosa; no trace of gypsum which might indicate brackish water or lagoons, is found. In short, the chemical composition of the Tuscaloosa strata as a whole is the composition of the residue of weathering of the Piedmont Plateau. Much of the material of the Tuscaloosa is arkose, the deposition of the Piedmont residue without sorting.

The remarkable purity of the kaolin, as indicated by the following analysis, is difficult of explanation. The analysis[1] is from a sample of kaolin from one of the mines at Dry Branch, and represents the condition of the clay in a state of nature, the sample having received no washing or other mechanical treatment.

Moisture at 100° C.	.93
Loss on Ignition	13.73
Silica	44.97
Alumina	38.51
Ferric Oxide	.51
Manganese Oxide	.00
Lime	.00
Magnesia	.16
Sodium Oxide	trace
Potassium Oxide	trace
Titanium Dioxide	1.36
Sulphur	.00
Phosphorus Pentoxide	.00
Total	100.17

[1] By Edgar Everhart, chemist for the Geological Survey of Georgia.

The kaolin contains:

Feldspar	.00		
Quartz	.33	Sand	.33
Mica	.00		
Ferric Oxide			.51
Clay substance			99.16
Total			100.00

It is not to be assumed that the entire thickness of a kaolin bed is as pure as the above sample, for the beds as a whole contain impurities, and the higher grades of clay are selected in mining, though the whole thickness of a bed may be white and comparatively of great purity.

In explanation of this remarkable purity, it would seem that nature operated a clay washing plant on a grand scale. The process was in the main that employed in washing a residual kaolin. The Piedmont Plateau was a vast residual kaolin deposit —to be sure the greater part of this deposit consisted of impurities such as particles of quartz, mica and smaller amounts of other minerals found in igneous rocks, which were subject to disintegration and decomposition by weathering agencies. The kaolin or kaolinite was derived mainly from the decomposition of the feldspars, though doubtless other minerals contributed to the amount in no small way. In the separation process, much of the coarser material and large rock fragments was dropped by streams in transit to the ocean, or at the debouchure of the streams, while the finer material, clay and sand, was carried further outward. Separation of the kaolin from the disintegrated mass was effected by the specific gravity of the minerals, and the fineness of grain, the latter having perhaps greater influence than the former. The specific gravity of quartz and kaolinite, for example, is nearly the same, 2.6, but the quartz never reached the degree of fineness of the kaolinite particles. Mica, because of the nature of its crystallization and the degree of fineness which the particle reached, remained in suspension easily, which accounts for its being such an abundant sandy impurity in the clay beds. Biotite and other iron-bearing minerals must have been

largely altered by leaching before their deposition, since they are comparatively rare either in the sands or clays of the Tuscaloosa.

On account of the brilliant red color of the soil of the Piedmont Plateau, the clay derived from it would be expected to have a high percentage of iron and to be distinctly colored, and the whiteness of the kaolins is perplexing. The iron-bearing minerals, silicates and magnetite, have generally a higher specific gravity than, and never reached the degree of fineness of, the clay; and, hence, did not remain as readily in suspension, and the absence of any high percentage of iron in the kaolin may be thus partly accounted for. Also, the red color of the Piedmont hills is due in the main to a coating of red iron oxide over quartz and other mineral particles, and often a decidedly smaller per cent. of iron oxide is present in the residual clay than would be imagined from a casual examination. The following analysis[1] of a Piedmont red residual clay will illustrate:

SiO_2	56.99
Al_2O_3	26.02
Fe_2O_3	1.91
CaO	.75
MgO	.17
Na_2O	1.91
K_2O	2.40
Ignition	9.76
Total	99.91

This is described as a bright red residual clay derived from a biotite-granite. It will be observed that the percentage of Fe_2O_3 is only 1.91 per cent.

Compared with the depth of residual decay, the red color, as mentioned above, is only a surface phenomenon, extending but a few feet in depth, and the great mass of underlying decomposed and disintegrated material is a mottled, gray or even white in color. It was principally from this great mass of gray or white residue that the kaolin beds were derived. The clay particles being the finest and of low specific gravity were carried farthest and dropped in the deepest and stillest water of the off-

[1] T. L. Watson, Geol. Surv. Ga. Bull., 9A, p. 87.

shore bodies described above. The impurities in the clay, as thus deposited, were only the very fine sand and some iron oxide, which may have formed a coating over the clay particles or fine sand grains. The greater part of the fine red and yellow iron oxide was dropped with the coarse sand grains, over which it formed a coating, or with which it was intimately mixed and from which it was not easily separable.

The absence of lime and magnesia is due to the fact that only a very small percentage of the lime and magnesia bearing minerals, of the igneous and metamorphic rocks of the Piedmont Plateau, reached a sufficient degree of fineness to be deposited in the stiller water with the clay. The lower Cretaceous is not a marine deposit; there is no evidence of animal remains, and conditions were not favorable for chemical deposits of lime or magnesium carbonates and sulphates.

There is no evidence whatever of impurities having been leached from the clay beds after deposition. On the contrary, the beds are probably more impure now than at the time of their deposition, on account of the infiltration of impurities from the overlying Tertiary formations.

MINERAL RESOURCES OF CHINA.

PART II.

BAILEY WILLIS.

III. TSIN-LING REGION.

The Tsin-ling region is so named from the mountain range which, stretching eastward from the Kuen-lung of central Asia, divides North China from South China between the parallels of 33 and 34 degrees, as far east as longitude 113. On the north the range is sharply bounded by great normal faults. On the south the basins and canyons through which the Han-kiang takes its course set a certain topographic limit, but they do not define the area of special geologic conditions which extends somewhat further south.[1]

The dominant geologic characteristic of the Province is metamorphism of all the rocks older than the Jurassic. There are very ancient schists which were metamorphosed before the beginning of the Paleozoic, but the Paleozoic limestones and shales themselves exhibit more or less general slatiness, schistosity, and rearrangement produced during a post-Paleozoic disturbance, and also local metamorphism in the vicinity of large granite masses intruded about the same time. These comparatively young granites are not readily distinguished from those which were intruded into pre-Paleozoic schists, and as both occur in very large masses we are unable as yet to describe the structure of the range satisfactorily.

Von Richthofen,[2] Loczy,[3] Obrutchoff,[4], and Willis and Blackwelder[5] have described sections across the Tsin-ling range. Von

[1] See Geology of Central Shen-si, Chap. XIV., pp. 299–317, in Vol. I., "Research in China," by B. Willis and E. Blackwelder, Carnegie Inst. of Washington, Publ. 54, and maps by R. H. Sargent accompanying.

[2] "China," Vol. II., pp. 557 to 658.

[3] "Reise des Grafen Szechenyi in Ostasien," p. 407 to 471, 1893.

[4] "Central Asia, Northern China, and the Nan-shan," by W. Obrutchoff, Vol. II., pp. 245 et seq. (in Russian).

[5] *Op. cit.*

Richthofen notes an occurrence of graphitic anthracite. The writer saw very irregular badly squeezed pyritiferous beds of the same material which were being worked on the Han, and a third occurrence is mentioned by Leprince Ringuet.[1] But in no instance are the deposits of anything more than local value.

Metalliferous deposits in the Tsin-ling region have not been described, but are supposed to exist. The geologic conditions are favorable to the supposition, as calcareous and carbonaceous rocks have been extensively intruded by granites, conditions which in other parts of the world have given rise to valuable ore bodies, and the field may be regarded as one which may repay prospecting.

Placer deposits in the Tsin-ling-shan and adjacent mountainous regions on the south are very limited, so far as recent gravels are concerned. The present surface is characterized by the corrosion of deep canyons, and gravels accumulate only locally and temporarily. There are older gravels, which correspond with higher channels formerly occupied by the streams and which rest on cut terraces at various elevations above the bottom of a canyon. Such a terrace, 40 feet high, occurs at Ping-li-hién, in southeastern Shen-si, where there is an abandoned channel of a large stream;[2] others[3] were noted in the northern Tsin-ling-shan up to more than 2,000 feet above the Hei-shui-ho. It is not known that any of these gravels are auriferous, but they probably may be.

IV. RED BASIN OF SSI-CH'UAN.

The Red Basin of Ssï-ch'uan, so named by von Richthofen on account of the red color of the prevailing rocks, is a remarkable depression, roughly estimated at something over 100 miles in diameter, surrounded by high mountains. It lies in western China, west of the 8,000- to 12,000-foot heights of eastern Ssï-ch'uan and east of the 20,000- to 25,000-foot peaks of nearby Tibet, but the elevation of the basin lies between 1,500 and 3,000 feet only above sea. The surface is deeply cut by many streams

[1] *Annales des Mines,* memoirs, 9th ser., Vol. 19, p. 400.
[2] "Research in China," by B. Willis and E. Blackwelder, Vol. I., p. 330.
[3] *Ibid.,* Atlas, geologic map sheet a³.

which are generally navigable, though in some cases only for shallow boats capable of running rapids.

The rocks of the surrounding highlands are pre-Paleozoic and Paleozoic chiefly, with minor areas of younger strata (early Mesozoic) and great bodies of intrusives, but the deposits in the basin are very late Paleozoic and early Mesozoic (Permian, Triassic, and Jurassic) strata, which are but slightly disturbed and only locally intruded by igneous masses. In general these sediments constitute red shales and red sandstones.

Coal, petroleum, natural gas, and salt are the chief mineral products of the Red Basin.

Coal.—Von Richthofen gives the following description of the occurrence of the coal deposits in the early Mesozoic strata:[1]

"The coal measures as a rule dip from the enclosing mountains toward the middle of the basin where they are covered with very thick sandy and clayey strata. The coal beds are restricted to the lower part of this formation and outcrop along the margins of the basin where they are worked at many places. Furthermore, the basin is traversed in its southeastern portion by folds which trend from southwest to northeast, in which the lower members of the coal-bearing strata occur. Along most of these folds coal mines are opened on both sides, especially where rivers cross the deposits, and, exposing the inner structure, make the coal readily accessible. In the west and north of the basin the coal is bituminous and of a better quality. Toward the south and east on the contrary it is inferior. . . . Coal which is so widely distributed is a great blessing for the people of the province of Ssï-ch'uan, especially as nearly all the rivers are navigable from their junction with the Yang-tzï to the boundary of the coal-bearing basin, and it is therefore possible to supply with cheap fuel all portions of the Yang-tzï region, which is at the same time the most densely populated district of Ssï-ch'uan. Nevertheless this advantage will remain restricted to the province itself, since there can never be an exportation of coal to the region of the lower Yang-tzï, as the product will not be able to compete successfully with the better coals of the province of Hu-nan. The low price

[1] "Die Kohlenfelder Chinas," *op. cit.*, p. 177.

of fuel will, however, be greatly to the advantage of steamers, which doubtless sooner or later will run on the upper Yang-tzĭ and its great tributary the Min-kiang and which can be supplied with fuel directly from the mines on the banks of the rivers."

Accounts of local occurrences may be found in the books cited below, but there are no reports on which to form an estimate of the amount of coal or conditions of mining.[1]

Gas and Salt Wells.—There is no more interesting illustration of Chinese ingenuity and patience than the drilling of deep wells with rope and a heavy tool by man power. A detailed account of the tools, methods, conditions, accidents, localities, and products, with many illustrations, is given by M. Louis Coldre, a Jesuit father, from observations during a prolonged residence in Ssĭ-ch'uan, and the following notes are condensed from his article.[2]

After locating a mountain range which bounds the Red Basin on the southeast and which runs from Wu-shan-hién on the Yang-tzĭ nearly parallel with the higher course of the river, Monsieur Coldre describes the distribution of salt wells as follows:

"Nearly all of the salt wells occur in the central portion of the province bounded on the south by the above described mountain chain, on the west by the river of Kia-ting (Min), and on the north by the first steep slopes of the mountains. The vast extent of this salt-producing region might lead one to think that there was an immense sheet of brine beneath the whole province, but in reality it is in the neighborhood of the final ramifications of the mountain chain that the principal salt-bearing regions occur. Of those which occur in the west, however, that of the district of 'Lo-chan' and 'Kien-ouy,' which is rich in salt wells but has no gas wells, offers no special peculiarity to

[1] "Description of Coal Field at Shui-kia-ho near Kuang-yuan-hién, northern Ssi-ch'uan," by L. von Loczy, in *Reise des Grafen Szechenyi in Ostasien*, Vol. I., p. 439. "Five Months in the Upper Yang-tse," Blakiston. "Through the Yang-Tsi Gorges," A. J. Little, 1888. "Three Years in Western China," A. Hosie, 1890, and in general in works on western China, see "Bibliotheca Sinica," by Henri Cordier, 2d edition, 1904.

[2] "Les salines et les puits de feu de la province du Se-tchoan," *Annales des Mines*, 8e série Mémoirs, Vol. 19, 1891, pp. 441–528.

distinguish it from the three other great groups of salt wells, 'Chee-hong,' 'Lan-pou,' 'Ta-lin' or from the general central region; whereas the district of the fire-wells, 'Fou-choen,' situated on the east of the chain, differs even in the aspect of its surface greatly from the country round about. The exploitations confirm this appearance, for the well-drillers encountered quite a different arrangement of strata from that which we have described for the central region."

Having given many details regarding the distribution of the groups of salt wells, with the names of districts and cities, the writer goes on to say:

"The total number of salt wells of which we have traced the distribution will approximate 10,000. Their output is extremely irregular and unequal. One of the wells of 'Tse-liou-tsin' (in the southwestern part of the basin) yields daily 350 large charges of highly saturated brine. Others, for example in the district of 'Pong-ky,' do not yield more than a single small charge daily of less saturated water. Between these two extremes there are all possible variations of production, and one would therefore form a very inaccurate idea of the richness of a salt-producing district by counting the number of wells."

As a type of wells in general, M. Coldre selects the group which he calls that of Les Grandes Salines, which is situated in the southwestern part of the basin, thirty miles north of the city of Sui-fu, between the Min-ho and the To-kiang. The market town adjacent to the salt field he names "Ta-chan-pou."

"After having traversed the long narrow streets of Ta-chan-pou, which are crooked and dirty as all Chinese streets are, one is greatly surprised on passing the last house to find ones self in a country of an entirely different aspect. The nature of the soil is changed. It is a mixture of yellow, friable sand, pebbly clay, and lime. There is scarcely any cultivation to be seen and one advances 7 or 8 li (2 or 3 miles) across a country where the vegetation is dwarfed, the rice seems to grow sorrowfully, and trees and bamboos are scarce. At last all cultivation disappears in the vicinity of the first wells. All of a sudden on rounding a hill one enters a little vale rich in salt springs, with a

forest of peculiar character, immense trees, trunks without branches and without leaves, many moving cords; these are the derricks and their accessories, the hoisting ropes which are joined to capstans, and the stays which are stretched in all directions. All this rises above the roofs of roughly built houses and from beneath the slopes of sheds built in all directions. To the grinding of pulleys and capstans in operation there is joined a human chant which resounds with the rhythm marking action. It is the song of the well-drillers springing upon their benches or that of the men attached to a capstan in place of buffaloes. Furthermore, one hears a deep, continuous and solemn reverberation. It is the voice of the earth, the sound of the gas of the fire-springs. . . . The general aspect of this country of the fire-wells is typical. It characterizes great activity in a primitive industry which draws from the earth its subterranean riches, at the cost of any risk, by manual force and patience. Not a bit of nicety, not a bit of taste, nor any progress. In the matter of construction, tools, machines, and methods, the sons of Tubal-Cain, the first ironworker, should have known at least as much, perhaps more. The marvel is that the Chinese succeed, thanks to their inexhaustible patience which counts on a result to-morrow if not to-day, or next year if it can not be reached this year."

It is not probable that any great reliance can be placed upon the geological deductions drawn from the descriptions of the strata passed through by the wells. It is said that in this particular southwestern district the stratification is very irregular and the strata disturbed so that there is great difference in the depth of wells at short distances from one another, and unsuccessful wells occur in the vicinity of very productive ones. In general the more saturated springs occur immediately above the supposed Carboniferous horizons and not in the upper part of the Trias as elsewhere. On the other hand " bituminous " accumulations occur frequently in connection with clay layers and some bodies of natural gas escape well above the Carboniferous, above even the least trace of coal, whereas others, and these the strongest ones, come from the deeper beds, in the transition horizons. Some wells yield only salt water or petroleum or gas; others

yield salt water and petroleum or salt water and gas at the same time. The Chinese distinguish and name the rocks only according to their color. Besides the yellow or gray Tertiary sandstone of the surface, of which the thickness varies from 38 to 100 meters, one finds successively red sandstone, gray limestone, and ferruginous oölite. Below the latter, at a depth of about 200 meters, bituminous accumulations are frequently encountered, it is said; beneath the oölite follow white and yellow sandstones of the Lias; then at a depth of 270 meters frequently occur abundant jets of gas. Still deeper occur bluish-gray marls and a white limestone (Permian). In these beds at a depth of 330 to 600 meters there occur yellowish brines of a moderate saturation. Then follow coal, limestone or sandstone of the coal measures, a brilliant brown rock assigned to the Silurian, and black and green shales. Beneath these last beds, at a depth of 930 to 1,100 meters, occur the bodies of black brine, the most saturated, and the most abundant and also the most important jets of gas. Most of the wells of the group of "Tse-liou-tsin" reach these depths and curiously enough they scarcely ever traverse the horizon of the yellow brine which supplies all the wells of "Kong-tsin." Dikes of gray granite, black basalt, and red porphyry frequently traverse the higher horizons and greatly retard the work of drilling.

The wells are drilled with a tool and rope which are attached to the short end of an unequally balanced see-saw. On either side of the longer end of the board is placed a bench. When at rest the weigth of the tool raises the long end of the board which is depressed by men who jump from the benches upon the board, thus raising the tool, and leap off again simultaneously, thus allowing the tool to drop. The stroke is about two feet. With shallow wells it suffices to have two men working at once, but as the well is deepened and the weight of the tool and rope increases, as many as ten men are required. The rhythmic action necessary to maintain this operation is obtained by means of a chant which the workmen sing in unison. It is stated that by having two sets of men who jump alternately as many as twelve to fifteen strokes a minutes are secured. According to the nature of the rock the

drilling may advance as much as several feet in a day or in hard rock scarcely an inch.

In regard to the character of the product we are perhaps most interested in that of petroleum. There are oils of four colors. The purest is white, like thin milk, and is sufficiently pure to give a clear light. Another of greenish-white is less valuable; then there is a yellow and a black oil; the latter is viscous, gives very little light and much smoke. The Chinese do not know how to refine these oils, and use them in the crude state in special lamps which are very tightly closed except for the passage of the wick, for the volatile hydrocarbons not having been distilled are very inflammable. The number of petroleum wells exploited is probably about 30 or 40 in the Grandes Salines, and perhaps 50 in the whole province.

The brines from salt wells are concentrated by evaporation and for this purpose, wood, coal, and natural gas are burned. The product of salt from the group of wells at the Grandes Salines was estimated by M. Coldre at approximately 250,000 metric tons per year, which, according to the same authority, was about half as much as the total production of France and two-fifths of that of all the provinces of Ssi-ch'uan.

V. SOUTH CHINA.

The region here designated South China comprises that hilly and mountainous country which extends in an arc from Shanghai on the northeast, parallel to the coast of Ton-kin and the extreme southwestern portion of the empire. It takes in the provinces of Fu-kién, Kuang-tung, Kuang-si, and Yü-nan, together with the southern parts of Kiang-si, Hu-nan and Kui-chóu. It is a country of marked relief but not of great altitude except in the western portion. In the east the valleys are relatively wide, and the hills or mountain ridges separated. In the west the rivers flow in deep and often precipitous canyons and the character is that of a deeply but not widely dissected plateau.

Throughout this entire region the dominant geologic characteristic is due to the presence of large bodies of intrusive rock (granite, quartz-porphyry, etc.), together with some volcanic

rocks which were erupted during the Carboniferous and which accordingly intruded and metamorphosed the earlier Carboniferous and older Paleozoic strata. Throughout the region there occur the ores of tin, copper, and other metals, which are probably intimately associated in genesis with the eruptive rocks, and there are also some ores of iron and numerous more or less extensive coal fields.

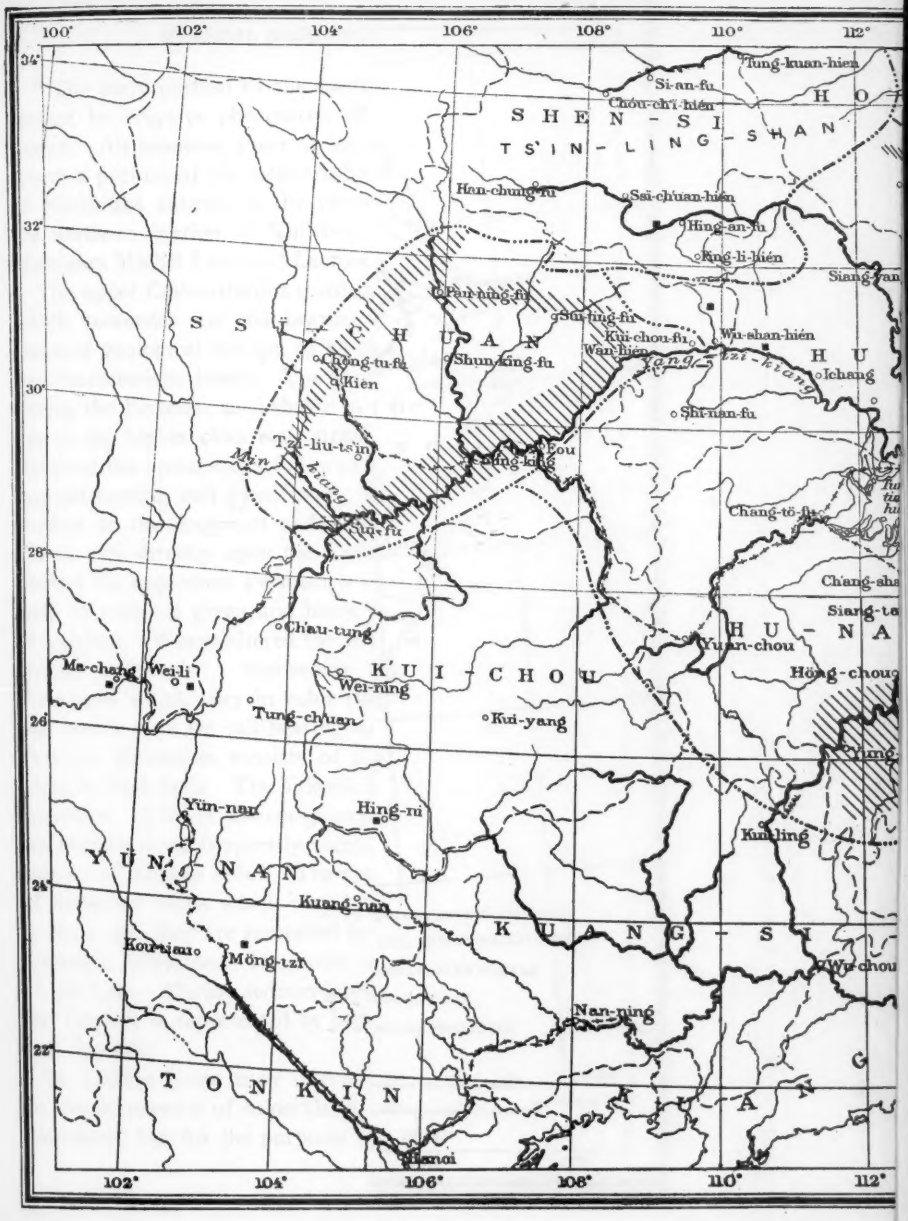
The region has been explored chiefly by French engineers who have penetrated from Ton-kin. The journey of Monsieur A. Leclère, who spent nineteen months in the southwest in 1897–1899, has yielded the most detailed information and reliable data available. M. Leclère's observations are published in numerous papers to various French societies, but the essential facts are comprised in the *Annales des Mines,*[1] from which the following notes are taken.

M. Leclère recognizes a number of distinct rock systems. Among these the oldest (terrains cristallophylliens) consists of various gneisses and associated intrusives. It is recognized as the basement of the sedimentary rocks in the higher regions of Ton-kin, but apparently there may be included with it in the descriptions, strata belonging to the Paleozoic which have been metamorphosed in the neighborhood of batholithic masses. There are certain limestones and quartzites apparently of great antiquity which were assigned by Loczy, and by Leclère after him, to the early Paleozoic (Sinian), but which may with equal probability be considered pre-Cambrian. Succeeding these metamorphic and in part old rocks come those which are relatively younger and are identified by fossils. The Devonian is apparently at the base and is succeeded conformably by strata of Carboniferous, Permian, Triassic, and early Jurassic ages. The Devonian and Carboniferous are generally calcareous, the passage from the strata of one period to those of another being characterized by an argillaceous or sandy limestone, above which come in sandy and argillaceous beds which include deposits of coal, that are often very regular but frequently high in ash. In this connection M. Leclère says:

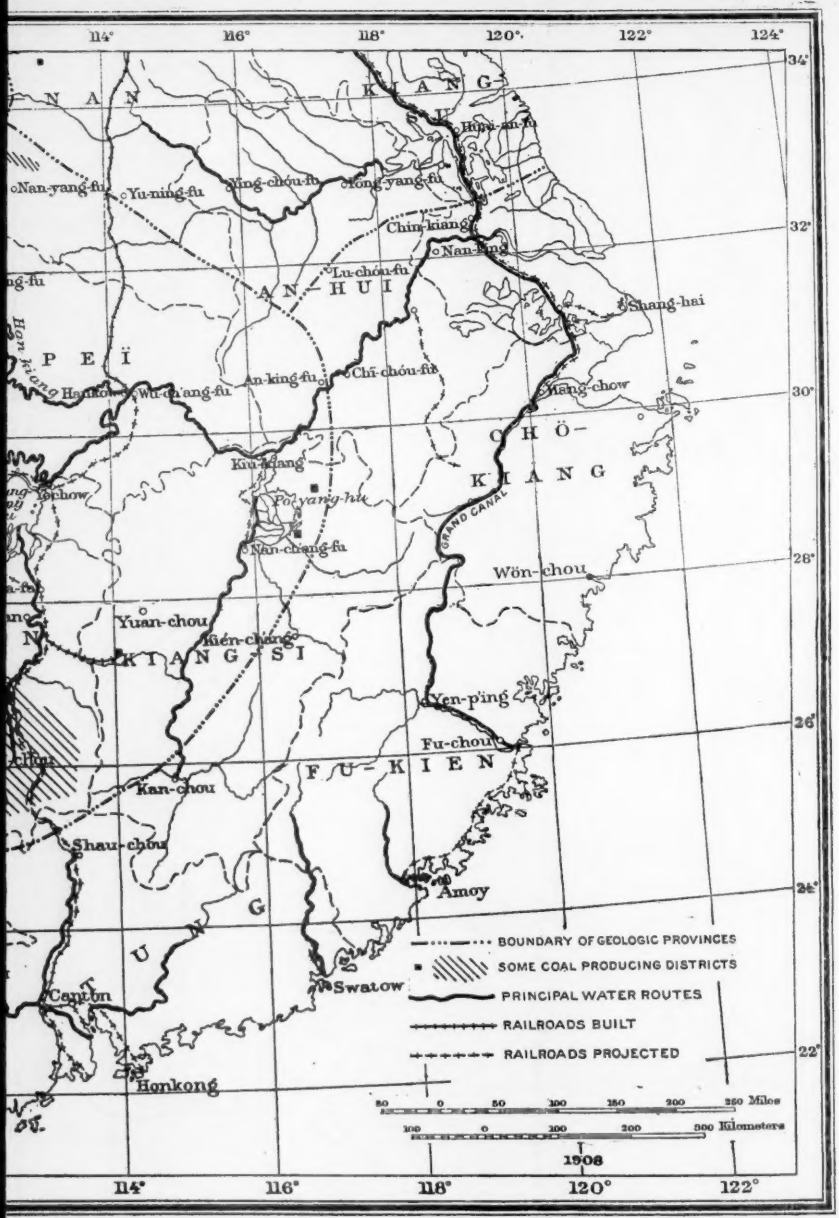
[1] "Étude Géologique et Minière des provinces Chinoises voisines du Ton-kin," *Annales des Mines,* 9 serie, Memoires, Vol. 20, 1901.

PLATE II

PLATE III



MAP OF CENTRAL AN



D SOUTH CHINA

"The early portion of the Carboniferous period was characterized by eruptive phenomena of remarkable importance and extent. An immense sheet of ancient lava which forms everywhere a portion of the southern border of the crystalline massif of Ssï-ch'uan extends to the vicinity of Yün-nan-sen and over the northern portion of Kui-chóu." The rock is described by Messieurs Michel Levy and Lacroix as labradorite melaphyre.

The upper Carboniferous consists of a very uniform limestone which succeedes the coal-bearing strata, constitutes the most constant geological horizon of all the region, and carries numerous characteristic fossils. The formation of limestone continued during the Permian, as is shown by the presence of fossils of that age in the higher calcareous strata. In Yün-nan and Kui-chóu the Permian limestone is followed by upper Permian beds which are salt-bearing and gypsiferous, but these strata are not found further to the southeast and in Ton-kin the lower Trias and Rhetic rest directly upon the Carboniferous limestone. Where present the uppermost Permian is composed of thick and regular beds of compact green and black shale traversed by little veins of gypsum. Where altered the rock takes on a peculiar characteristic wine color. Succeeding this shale occur thin-bedded limestones which vary in color through yellow, red, and green and which also are salt-bearing and gypsiferous. The highest Permian formation consists of a characteristic red sandstone, often in thick beds. The Triassic is represented by an important limestone. A lower less conspicuous part consists of bluish shale, but the limestone frequently forms the crests of the peaks in the regions of marked relief. The upper Triassic or Rhetic consists of iridescent marls which vary in color from rose through blue to black, and they are succeeded by lower Jurassic beds of yellow dolomitic limestone. The latter overlies a coal-bearing horizon of the Lias. Marine sedimentation closed with the Triassic but the Tertiary is represented by beds of sandy shale which include coal deposits.

M. Leclère gives many interesting details of his observations on the occurrence of minerals in the descriptions of his several itineraries, but for the purposes of this article it must suffice to

abstract the summary which he gives regarding the mineral resources.

Coal.—Coal beds of Paleozoic age occur at various horizons from the Carboniferous to the middle Permian. The beds, as might be anticipated from the general structure of the region, are not very thick. Upon a general estimate that the area within which they are known to occur has an extent of 110,000 square kilometers and that the average thickness of the coal is 0.1 meter, it is believed that there is a total of ten billion metric tons.

It is not clear upon what basis this estimate is made. From the geologic descriptions it is evident that the coal strata do not extend horizontally over the area and one is left to infer from the very small thickness assumed, that the writer has in mind beds which have an average actual thickness of perhaps one meter, but which are present over only one-tenth of the area. In any case the estimate has little value as a measure of the resources in Paleozoic coals. These coals as a rule are high in ash.

The Mesozoic coals, especially those of the Rhetic, are described as of great extent but moderate thickness. Several different fields (those of "Mong-tze," "Hing-gni," "Ma-chang," and "Houei-li" (Wei-li), and that of "Kouei-gny") are specially noted, and it is estimated that they contain approximately 20 billion metric tons. These coals of the Rhetic are quite different from those of the Paleozoic. They are generally purer, are flaming coals, and yield a light coke. The Tertiary coals of "Yen-bay" are richer in volatile matters than those of the Rhetic, but also higher in ash. They are of very moderate extent and not regular.

Iron.—Outcrops of hematite, which are worked in those districts where charcoal is still available, are not infrequent, as is natural in a region so traversed by veins as is Yün-nan. In the northeast of Kui-chóu ferruginous nodules occur characteristically at the base of the lower Lias, and kidneys of iron carbonate are found at certain of the coal-bearing horizons of the Carboniferous limestones. Their value as a resource in the future development of the country is not highly estimated.

Tin.—The mines and smelting works of tin of the region of "Ko-Tiou" are at the present time the most important industrial developments of Yün-nan. They lie between 2,200 and 2,700 meters above sea, in the mountains between "Mong-tze," "Lin-ngan" and the Red River. Their production appears to have attained its maximum of about 3,000 tons of crude tin, which is produced by a population of 30,000 individuals. The deposits are in no sense alluvial. They are obviously vein deposits. The cassiterite is always enclosed in a red clay, contained sometimes in fissures in limestone, sometimes in the neighboring accumulations of soil. There is no doubt that these occurrences are the result of decay in the upper portions of ancient veins. As the exploration goes deeper, foreign metals appear and finally predominate, at first in the form of oxides and then in that of sulphides. The richness of the region in tin may perhaps be due to the existence of tourmaline-bearing pegmatite which is injected across the sedimentary formations up to the lower Trias. It is, however, worth noting that even in the deposits of copper which occur in the midst of masses of porphyrite, analysis shows the presence of a considerable quantity of tin. The two metals are therefore not distinctly separated. The resources of "Ko-Tiou" in tin can not easily be estimated. It is known that deposits of this sort are liable to run out suddenly and it is much more difficult to define their probable depth than in the case of alluvial deposits. The production is limited not so much by the rather high price of charcoal employed in reducing the tin, as by the small quantities of available water. The operation of washing the ores is effected by the most rudimentary methods, but such is the nature of the mineral and the expertness of the Chinese that the extraction is pushed to its utmost limit. For some years past the crude metal has become richer in copper, lead, and arsenic. It is all sent across Ton-Kin to Hongkong.

Copper.—Copper has been exploited in southwestern China at least for a thousand years and probably for a much longer time, and records of the production are said to have been preserved in the library at Yün-nan city. The product is used for the

coinage of copper cash, the only coins in general use throughout the empire, and as the value of the coin depends upon the price of copper, the product has been in some measure regulated by government control. In the seventeenth century at least 6,000 tons were produced annually; at present about 1,000 to 1,500 tons. The diminution is not a result of the exhaustion of the deposits, but rather of the disappearance of the forests. On account of the lack of charcoal only minerals of the most exceptional richness or those which are most accessible are worked. Among the copper minerals and copper-bearing rocks Leclère mentions chalcocite, cantonite, and copper pyrite as occurring in veins in the carbonaceous shales; layers of cuprite and of native copper intercalated in porphyrite; and sandstones of the Trias impregnated with carbonate. The principal deposits which are worked occur in Triassic limestone, the mass of which is impregnated by diffusion from veins with the formation of a carbonate enclosing only traces of pyrite. The veinlets take the form of concretions arranged in zones which follow the natural fissures of the limestones. The principal centers of extraction are those of "Toungtchouan," "Oui-si" near "Li-king," and the vicinity of "Oueining" (Wei-ning) in Kui-chóu, which produces much zinc and lead. The works at present do not accept any minerals which will not form a matte containing 20 to 30 per cent., a richness which can only be obtained by hand-sorting, at which the Chinese are very expert. Minerals which do not contain more than 15 per cent. remain upon the mine dump and form considerable masses. The facts stated show that the province of Yün-nan still contains very considerable resources of copper-bearing minerals, chiefly in those deposits which were beyond the reach of the ancient methods of exploitation. Only general conclusions, however, can be drawn, and a special study of each deposit would be necessary to fix its value.

Lead, Zinc and Mercury.—Veins containing lead minerals are less numerous than those of copper. They are only worked to a notable extent in the vicinity of "Ko-tiou" and "Ouei-ning." Only those superficial ores which have been transformed into carbonates are used.

Deposits of calamine are still superficially exploited near "Kui-tsing" and "Ouei-ning."

Deposits of mercury, which is widely distributed through the southern province of Kui-chóu, are not considered by Leclère to have great promise for the future. He deems it probable that the Chinese, who have made great use of cinnabar and of the metal, have worked the available deposits until they are to a very great extent exhausted. The fact that the exploitation, which was interrupted by the Mohammedan rebellion, has not been extensively resumed leads him to think that the remaining deposits are not rich, but he says without doubt the question is worthy of further investigation.

Gold.—Gold mines are said to be very numerous in the western region where the Miocene folds of a north-and-south trend are superimposed upon older structures. The quartz veins have never been deeply worked by native methods. At present the only place where gold is extracted is at the mine of "Ta-lan" near "Se-mao." While this point was not examined by M. Leclère he states that the reports leave no doubt of the aurifeous wealth of the eastern portions of Tibet and Burmah.

Salt, cobalt, manganese, realgar, and antimony are also mentioned as occurring in the provinces visited by M. Leclère.

The preceding notes are restricted to the southwest portion of the Chinese empire, that being the region to which the French engineers have necessarily confined their explorations. It is a country which has been extremely inhospitable to strangers, and the observatieons which have been made have been limited by the fact that the traveler was really liable to be mobbed by the rough mining population. The tone of M. Leclère's statements is, however, conservative and there is little doubt that this portion of China possesses very considerable wealth at least in tin and copper and the mineral fuels necessary to their reduction.

The eastern portion of the region under discussion lying in the provinces of Fu-kién and Chö-kiang, is even less well known and so far is without any special reputation as a mineral-producing district. Quartz porphyries similar to those of the southwest

were collected by von Richthofen and have been described by Kollbeck.[1] So far as the descriptions go the rocks appear to be of types similar to those which are common in the western United States.

According to a report attributed to an American mining engineer[2] there is a large body of magnetic iron ore estimated to contain 10,850 short tons near Amoy in Fu-kién. Such a deposit might be of great value. Kaolin, galena, and zinc are mentioned as occurring in the same region.

This necessarily partial account of the mineral resources of China may be closed by a reference to the relations of the Chinese to foreigners and foreign capital, as the writer understands them.

The attitude of the Chinese toward a foreigner at first is one of intense curiosity in regions where they are not accustomed to strangers, followed by friendly or unfriendly treatment, according to what they find him to be. There are many who will mischievously annoy and some who are keen to take advantage; but there are more who respect rank as shown in character and learning, and a square, steady, considerate man will usually have no serious trouble among them. Unfortunately they too often find the foreigner "ignorant of restraint," and he is least liked where he is most often met.

Through costly experience the Chinese officials have learned that the presence of a foreigner entails grave responsibility for his safety. It is the testimony of every traveller who has deserved well at their hands, and of many who have not, that they as a rule exert themselves to protect the stranger and to forward his reasonable purposes. On the other hand, the more or less crystallized sentiment is now "China for the Chinese." The Imperial Government has bought back railway and mining concessions so far as practicable. Exploitation by foreigners is not wanted. Foreign capital is wanted, is indeed absolutely necessary

[1] "Ueber Porphyrgesteine des südöstlichen China," *Deutsche Geol. Gesell. Zeit.*, Band 35, 1883, p. 461.

[2] U. S. Daily Consular and Trade Reports, Bureau of Manufactures, Dept. of Commerce and Labor, Washington, D. C., May 3, 1907, p. 10.

to adequate development of railways and mines, but the policy is to accept it only on condition of Chinese control. It remains to be seen how soon China can establish that confidence in her business methods and credit which alone will invite investments on reasonable terms. Reforms of her finances and taxation are fundamentally necessary to that end.

A PRACTICAL CLASSIFICATION FOR LOW-GRADE COALS.[1]

MARIUS R. CAMPBELL.

During the progress of the Second Geological Survey of Pennsylvania a scheme for the classification of coals on the basis of fuel ratios was proposed by Persifor Frazer, Jr.,[2] and this scheme has come to be generally adopted by the trade for high-grade coals.

Fuel ratio as defined by Frazer is the quotient of the fixed carbon divided by the volatile matter, as shown in a proximate analysis. Although the relative proportion of fixed carbon and volatile matter depends to a certain extent on the method employed in making the analysis, the variation in high-grade coals is small, and hence the classification for coals of this kind is fairly satisfactory, but whether satisfactory or not it is so well fixed in the trade that it may be considered as established beyond the shadow of a doubt.

The question that confronts the coal trade at the present time almost more than any other is what classes of low-grade coals shall be recognized, and what are the criteria for their differentiation. Fuel ratios do not apply for the reason that when this ratio falls below 2 there is no regular nor decided change in passing downward in the scale, and by it lignite cannot be separated from bituminous coal.

Until within the last few years only a small number of ultimate analyses of coal were available, and many persons believed that when such analyses were at hand a classification could be devised that would separate all grades of coal on a chemical and

[1] Published by permission of the Director of the United States Geological Survey.

[2] Frazer, Persifor, Jr., "Classification of Coals," Rept. MM., Second Geol. Survey Pennsylvania, 1879, pp. 128–158; *Trans. Amer. Inst. Min. Engineers*, Vol. VI., 1879, pp. 430–451.

a purely scientific basis. At last such analyses are at hand,[1] but careful study of them fails to reveal any classification[2] that conforms to the facts and at the same time has a scientific basis. For a long time the writer has been of the opinion that such a classification were possible, but at last he has been convinced that while certain schemes apply to coals of a limited range or quality, the differences in the low-grade coals are really physical and no scheme based entirely on chemical composition will be adequate unless the chemist can determine the various hydrocarbon compounds rather than the chemical elements that are involved in the composition of the coal. Besides the demand of the trade is not for a scheme based on ultimate chemical analysis, for such analyses are expensive and require considerable time for their completion. The demand of the practical man is for some means that is always at hand, and such criteria must necessarily be either the physical appearance of the coal or its behavior under certain normal conditions.

In a general way the trade recognizes two great groups of coals below the bituminous class. The most valuable of these groups is closely allied to bituminous coal; in fact the two groups merge one into the other by insensible gradations. These coals are black, frequently of brilliant luster, and are commonly known as "black lignite," "lignitic coal" or "lignite." As a rule they contain more moisture than the bituminous coals and less than those belonging to the next lower group, but the moisture content of coals varies so irregularly and depends so much upon the condition of the sample analyzed that it is not a safe criterion upon which to base distinctions.

The lowest group is brown in color, generally woody in texture and is known as "lignite," "brown lignite" or "brown coal."

[1] Bulls. U. S. Geol. Survey Nos. 261 and 290; Prof. Paper No. 48.

[2] Campbell, Marius R., "The Classification of Coals," *Trans. Amer. Inst. Min. Engineers*, Vol. XXXVI., 1906, pp. 324–340; "Report on the Operations of the Coal-testing Plant, Pt. 1, Prof. Paper No. 48, 1906, pp. 156–173.

Parr, S. W., "Composition and Character of Illinois Coals," Illinois State Geol. Survey, Bull. No. 3, 1906, 49–54.

Grout, Frank F., "The Composition of Coals," ECON. GEOL., Vol. II., 1907, pp. 225–241.

These groups are natural divisions and are already in use in the trade, but there are no sharp lines of distinction between them, and it is difficult to say where one ends and the other begins. No one questions the existence of the groups, but the trouble is to establish the criteria by which they shall be separated and the name that shall apply to each. The presentation of criteria of this character and names for the various groups are the objects and excuse for this paper.

The demand for appropriate names for these groups became so imperative during the past year that a conference was held by all geologists of the United States Geological Survey interested in the subject of coal, to decide if possible on what names should be used in the publications of that bureau. After considerable discussion it was decided to drop the term "lignite" in all its forms as applied to the group of coals next below the grade of bituminous, for the reason that in no sense are these coals woody, as the name "lignite" implies, and also because the term "lignite" or "lignitic" seems to imply a poorer quality than these coals actually possess. Since the term "semi-bituminous" as applied to the group above the bituminous is too well fixed in the trade to be displaced, the term "sub-bituminous" was recommended and formally adopted by the survey for all official publications.

Similarly, the term "lignite" was adopted for the lowest grade, restricting its use to those coals which are either actually woody in structure or closely approach wood in their composition. No attempt was made to define these terms, other than that stated above, and the delimitation of the groups was deferred until further evidence could be obtained upon which to base a classification.

The names of the groups of coal now recognized by the United State Geological Survey are therefore as follows: (1) Anthracite, (2) semi-anthracite, (3) semi-bituminous, (4) bituminous, (5) sub-bituminous, and (6) lignite.

Although groups 4, 5 and 6 of the above scheme are in general sharp and distinct, they merge, and their actual separation will always remain a matter of doubt. In general, however, they

have certain characteristics which the writer believes will serve for all practical purposes as a means of their separation.

In dealing with these low-grade coals it has been the practice of many mining engineers and geologists to class all coals as lignite if they give a brown streak. This mode of classification is very objectionable, since it brings together all of groups 5 and 6, and includes many coals which the writer believes should be considered as belonging to group 4, but since this involves the present criteria it will be more fully discussed later.

The criterion upon which the writer proposes to separate bituminous (4) from sub-bituminous (5) is solely that of weathering, a criterion which one may readily apply to both fresh and weathered coal, and therefore at the command of the most inexperienced when once he has understood how to apply it.

The manner of weathering of coal depends entirely upon the degree of transformation or metamorphism that it has undergone. The writer[1] believes that the progressive change in vegetable matter from wood to lignite and then on through the various grades of coal noted above, while due to chemical changes induced by heat (ordinary temperatures), is controlled almost wholly by the escape of the gases which are the products of the chemical change. If the conditions are such that the escape of gases is unobstructed, the transformation will be rapid, but on the other hand if the gases escape slowly and only with the greatest difficulty, the change in the coal will be correspondingly retarded. Gases escape through joint cracks and cleavage planes, therefore highly developed cleavage in a general way indicates high-grade coal. This is well illustrated in the structure of the Pocahontas coal, as shown in Fig. 1, of West Virginia, the Pittsburg coal, of Pennsylvania, and the Huntington, or Jenny Lind coal, of Arkansas. The converse of this is generally true, namely, that the absence of cleavage is indicative of low-grade coal, either lignite or sub-bituminous. An excellent example of this lack of structure is shown in the Texas field, where joint planes in the beds of lignite are frequently three or four feet apart.

[1] "Hypothesis to Account for the Transformation of Vegetable Matter Into the Different Grades of Coal," ECON. GEOL., Vol. I., No. 1. pp. 26–33.

EXPLANATION OF PLATE IV.

FIG. 1. Sub-bituminous coal from Philippine Islands, showing characteristic weathering cracks.

FIG. 2. Pocahontas, West Virginia, coal showing structure.

(Both specimens are coated with ammonium chloride.)

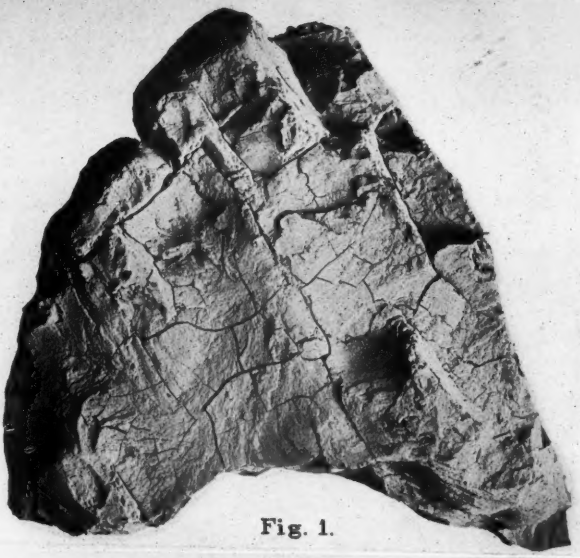


Fig. 1.

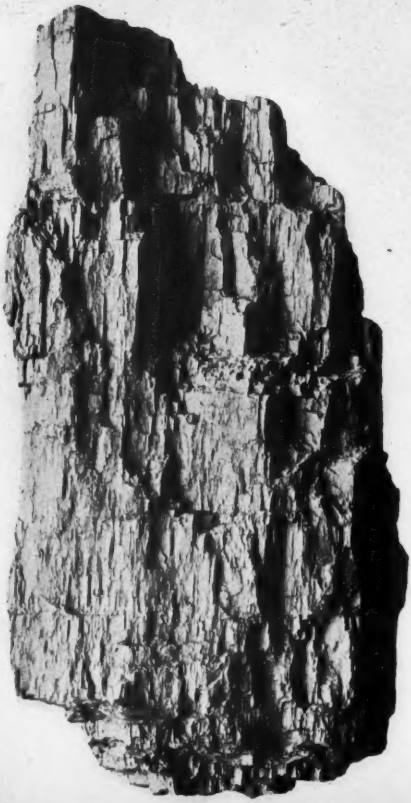


Fig. 2.

The development of cleavage is not, however, an infallible guide to the present character of the coal, for time is an element that enters largely into the transformation and frequently the same result may be accomplished by a powerful force acting quickly that would take a weak force a much longer time for its accomplishment. Therefore some coals very young geologically but subjected to very strong dynamic forces may have cleavage as well developed as the very oldest Carboniferous coals, but the time may not have been sufficient for the material to have been changed into bituminous coal. An excellent example of this development of cleavage without a corresponding change in quality may be found in some of the sub-bituminous coals on the west face of the Cascade Mountains in the state of Washington.

From the foregoing statement it is apparent that cleavage alone cannot be used as a criterion for the separation of bituminous from sub-bituminous coal, but it is of great assistance when used with discretion.

Another difference, and perhaps the one most to be depended upon, is the manner of fracture on drying. Coal as it comes from the mine almost always carries a variable amount of moisture, from which it will part readily upon exposure to a dry atmosphere. In parting with this moisture, cracks are formed which vary greatly with the kind of coal involved. In bituminous coal the cracks generally will correspond with the cleavage, and the fragments will remain prismatic in shape even though divided into minute particles scarcely visible to the eye. Exception is to be noted, however, in the case of cannel coal, splint coal, and many forms of block coal, of which the Brazil coal of Indiana may be considered the type. These coals always show cleavage faces on large blocks, but the blocks do not split readily. These coals generally have other characteristics by which they may be identified without recourse to their weathering properties, therefore it is not necessary to consider them further.

Sub-bituminous coal may in exceptional cases, as noted above, have cleavage well developed, but as a rule it is poor and shows only on the larger blocks. When lump coal of this character is exposed to dry air it checks irregularly, and when the fragments

separate they are irregular in outline. What the writer believes is characteristic weathering of sub-bituminous coals is shown in Plate IV, Fig. 1, which is reproduced from a photograph of a lump of coal from the poorer grades of the Philippine Islands.

The weathering of the lump of coal shown in the figure is in its incipient stages. If it were continued the pieces would fall apart and in turn would check and break up until carried to its ultimate end, the lump would be reduced to a heap of small fragments of irregular shapes and bounded by rough faces instead of cleavage planes.

The final criterion upon which the writer depends is the separation on weathering of the sub-bituminous coal into plates parallel with the bedding. This criterion is particularly valuable when applied to a badly weathered outcrop, for one can readily detect the little plates no matter how small they may be. So far as the writer has observed, this feature never shows in bituminous coal except in a very small degree and when the laminae of the coal are separated by films of earthy matter or of mineral charcoal. In applying these criteria some coals will be classed as bituminous which have a brown streak, are geologically young, and generally have been regarded as lignites or lignitic coals, but they resist the weather, stand shipment well, and have a high calorific value, which makes them to all intents and purposes bituminous coal. A good example of this change may be seen in a coal which occurs in Stone Canyon, Monterey County, California. By the general standards of the Pacific Coast this coal has been classed as a lignite, but it exhibits little or none of the weathering properties of sub-bituminous coals as specified above. Its ability to withstand weathering is shown in the following reproduction from a photograph which shows lump coal that, according to report, has stood in piles with vertical walls for about three years.

Certainly a coal that can stand exposure to the weather like this and shows a calorific value of 12,700 B. T. U.'s, should be classed as a bituminous coal. Caution should be used, however, since coals on the borderland between the groups will exhibit the weathering properties of both, and the dominant features must

be used in determining the class. Of course in such cases too independent observers may place a certain coal in different groups, but this is no argument against the criteria upon which it is based, since it must be understood that there are no sharp lines of division between the various groups.

The criterion for the separation of lignite from sub-bituminous coal is that of color only, and as might be expected, no hard and fast line can be drawn. In general the lignite of North Dakota is brown, lusterless and woody, but toward the west it changes

FIG. 12. Coal of Monterey County, California, showing no weathering in piles of lump coal which have stood three years.

gradually into black, shiny, sub-bituminous coal. The change from brown to black is gradual, and as the color changes the lignite loses more and more of its woody character. Near Glendive, Montana, it is black but lusterless. At Miles City, its color is a little more pronounced, and much of it is black and shiny, and at Sheridan, Wyoming, it has practically lost all traces of its woody structure, and has obtained a brilliant luster throughout.

In attempting to separate coals from these various localities great difficulty will be experienced, and it is probable that no two observers will agree as to the place where the line of division shall be drawn. This does not, however, affect the validity of the two groups, but merely shows how closely they are united.

In the lignite field of the gulf no such difficulty is experienced, since these lignites are separate and apart from all other fields and no coals are known to occupy the transitional zones between them and the higher grade coals of the sub-bituminous group. The Texas and Arkansas lignites, however, are very unlike those of North Dakota in that they are not woody in texture, but instead are homogeneous and earthy in their texture and appearance. As far as their chemical composition and fuel values are concerned they belong in identically the same class as the lignites of North Dakota. The woody texture does not seem necessarily to be a characteristic of this group of coals, but rather to depend on the character of the vegetation from which they were derived.

RÉSUMÉ.

The essential points of this paper may be briefly summarized as follows:

1. The recognition of two classes of coal below the grade of bituminous.

2. The restriction of the name "lignite" to the lower grade, and the application of the name "sub-bituminous" to the higher grade, in conformity with the usage of the United State Geological Survey.

3. The recognition of weathering as the criterion for separating the sub-bituminous from the bituminous grade of coal.

4. Manner of weathering divided into two classes: (*a*) Irregular breaking in sub-bituminous coal as opposed to cleaving into prisms in bituminous coal, and (*b*) separation along bedding planes into plates in sub-bituminous coal.

5. Separation of lignites from sub-bituminous coal on the basis of color, the former being brown and the latter black.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor.

THE LOCALIZATION OF VALUES OR OCCURRENCE OF SHOOTS IN METALLIFEROUS DEPOSITS.

Sir:—The fact that all portions of mineral veins or ore deposits are not equally rich and that the valuable or workable areas form but limited portions of the entire deposits is well recognized. Every mining engineer who has conducted careful sampling has realized this fact, and often an important part of his work in the formation of accurate estimates of value consists in the delineation of those areas of ore which are sufficiently high grade to pay. In some cases the high grade areas are so small, occur with such irregularity, and are scattered in such numbers within the mineralized mass that it is impossible either in estimating or mining to discriminate between them. In such cases the ore is described as "spotty," and an average estimate must be made upon which the valuation may be based. Large high grade areas which are extremely irregular in form, likewise give rise to difficulties, and often so seriously affect results of sampling as to remove them beyond the bounds of reasonable accuracy. On the other hand, it frequently happens that the segregations of high-grade ore follow definite directions and are repeated with more or less similarity of occurrence and regularity of position.

There are few, if any, ore-deposits, the world over, which may be entirely extracted at a profit; where the values are so evenly distributed throughout the whole mass as to render few assays necessary; or where great masses of low-grade material are not

either abandoned or left until improved conditions of exploitation bring them within the limit of profitable work. In some cases which seem to be exceptions, further work usually later reveals the limited nature of the high-grade portions which earlier operations had not been sufficiently extensive to show. In other cases, all of the ore has actually been profitably mined but examination of assay-plans would show that some restricted portions of the mass were much more profitable than others and complete extraction of the ore was merely due to fortunate conditions which brought the lowest grades of ore within the limit of profitable exploitation.

If the laws which govern the occurrence of such variations can be formulated, or where understood can be clearly stated, it should greatly facilitate the estimate of value and the accuracy of the prediction as to what may be expected in the unexplored masses of ore deposits.

In opening this discussion it is not so much my object to present any new facts as to state briefly some of the features now known, and by so doing to call attention to those aspects of the problem that are least understood and where discussion seems especially pertinent.

A clear definition of terms would at the outset seem important. Where a segregation of higher values in surrounding, or intervening, low-grade material is observable in an ore-body, the high-grade mass, if of sufficient size and sufficiently regular form, is usually termed a *shoot*.[1] Masses of more or less equal diameter in horizontal, but of great comparative vertical extent are termed *chimneys;* if of smaller size, *pockets, nests, bunches* and *spots* are the terms used. *Bonanza* is a term often employed, especially in describing very rich masses of the ores of gold and silver. It has also been applied to ore masses due to accidental secondary enrichment and it might be well to restrict it to such usage.

[1] This is sometimes erroneously written *chute,* a term which it seems wise to restrict to the run-ways used for the transfer of rock, ore, etc., from higher to lower levels. The term *course* is used in England, see Philips, *Ore-deposits,* p. 94.

In all of these cases the definition of the rich mass is based upon profitable extraction. Thus *shoots* are often called *pay-shoots* and are usually considered as those portions of ore-bodies which carry a sufficiently high content of ore minerals to be worked at a profit. As such a definition is purely commercial and will, therefore, vary with the fluctuations of the market and the facilities for development, it may better be extended to cover all masses of ore which carry a higher content of ore minerals than the adjacent material. Such ore minerals are generally speaking metalliferous, but not necessarily so; shoots may be as readily conceived to occur in deposits where a non-metallic mineral is sought—for instance barite veins—as in metallic ore deposits.

Again the term shoot cannot be restricted to high-grade material in a low-grade matrix. It is used to describe other features of ore-deposits, than the high grade masses within the body of the deposit itself. Thus lenses or bodies of ore occurring along a fissure are termed *shoots* when no material, even barren gangue, is present along the intervening portion of the fissure; linear masses of ore separated by barren country rock are said to occur in *shoots*—in short, any ore body of which one diameter is very much greater than the other two may be so called.

One can hardly quarrel with the application of the term as so used, as it would be difficult to suggest a more appropriate one—but it is well to understand these different usages. In the discussion which follows, for the sake of clearness, the high-grade areas in low-grade matrices will be termed *shoots of variation* and the latter group *shoots of occurrence*. The last will be discussed first.

Besides this two-fold usage of the word shoot, the question is further complicated by the processes of weathering. In former years, before the effect of the chemical changes due to weathering on an ore deposit were so clearly understood, the question was much more perplexing than at present. No distinction was then made between the rich products of superficial alteration, oxidation and secondary enrichment, and the variations in value of the primary ores. Causes suggested as explanatory of the one

were to all intents logically applicable to the other, so the difficulty and complexity of the question was thus much increased.

It is now easy to exclude, as more clearly understood, the oxidized ores, the rich secondary zones of ore-deposits and in many cases the great bonanzas of secondary sulphides which are developed by atmospheric waters entering the unaltered sulphide zone along lines of fracture or faulting.

Such are the great chalcocite zones at Butte, Montana (at least in part); the chalcocite masses in the Alaskan Copper River region; the rich secondary zones in the pyritic copper deposits of Ducktown, Tennessee; and many others. Variations in value of this kind usually find expression in vertical directions, that is, the change occurs at some more or less definite depth, and the position of the resulting shoot or area of high values is approximately horizontal, the values grading from high to low vertically and not in the direction of strike. The mineralogy also often forms a means by which the zone of enrichment can be recognized. Certain minerals as chalcocite, bornite, argentite; or certain associations of minerals are chiefly characteristic of zones of secondary sulphides, and assist materially in the detection of such zones. The processes by which these richer portions have been developed derive their potency entirely from surface waters and, while they are far from being entirely comprehended, the resulting shoots and bonanzas can usually be referred with measurable certainty to the immediate or ultimate effects of weathering. With variations in the value of different portions of individual veins or ore-bodies which are distinctly *not* the effects of weathering, variations in the *primary* ore-bodies as originally deposited, the case is not so simple and the differences in value are much more difficult to explain. In this paper the effects of weathering are disregarded and only the shoots in the primary ores are considered.

The accompanying provisional grouping may be here introduced for the sake of clearness:

SHOOTS
- SHOOTS OF OCCURRENCE
  - Due to available open space.
  - Due to chemical effect of wall rock.
  - Due to impounding of mineral waters.
- SHOOTS OF VARIATION
  - Due to chemical effect of wall rock.
  - Due to intersecting veins.
  - Due to causes not fully understood.

SHOOTS OF OCCURRENCE.

The first type of shoot, which I have called a *shoot of occurrence,* is that in which the occurrence or non-occurrence of mineral whether high-grade, low-grade or barren determines the existence of the shoot. The entire ore-body is often workable and as a whole constitutes a shoot.

In the case of a fissure vein such a shoot is separated from the next succeeding one by a fissure so constricted that no ore occurs at all. In the case of long linear or lenticular bodies in limestone or other rocks and not fillings of fissures, shoots or masses are separated from one another by intervening areas of barren rock.

The tendency of ore-bodies to assume linear form is due to both mechanical and chemical causes. The mechanical cause most frequently observed is the variation in the amount of open space available for deposit. The chemical cause is the effect of the wall rock in promoting replacement by material in solution.

Available Open Space.—In the case of veins formed by the filling of open fissures, the causes which determine the character of the fissure will determine also the amount of opening available for deposition. Most fissures are characterized by a certain amount of movement or faulting. If the fissure is a perfect plane the amount of opening during faulting will be directly proportional to the gaping of the walls and will not vary materially from place to place; there will be merely a gradual diminution in the width of the vein, both in the direction of strike and with increasing depth. But fissures are almost never perfect planes; rather are they warped surfaces, undulating both in direction of strike and with depth. Observations of the writer of the great faults at Leadville, Colorado, in the Black Hills and in other districts offer evidence of the curved surfaces of fault fissures.

One of the most frequent errors of geologists and engineers is the assumption that faults are plane surfaces, and that their strike and dip may be plotted by protractor and indicated on sections and plans by straight lines. This is practically never true. No fault fissures which have come under my observation are absolutely straight; few do more than approximate a constant direction. Even slight differential movement along such warped surfaces is capable of producing an open space. De la Bêche,[1] Phillips[2] and Beck[3] have shown how pinches and swells may arise from the tendency of fractures to follow curved lines. Movement along the plane of faulting may thus give rise to pinches and swells, even where no actual gaping of a fissure occurs. The swells are then produced by the juxtaposition of two concavities and the pinches by the like position of two convexities. If movement takes place both laterally and vertically, such pinches and swells, if followed downward may be found to afford lenticular spaces for the deposition of ore which in a longitudinal projection of the vein or on an assay plan will find expression in vertical or inclined, and generally more or less upright shoots, separated by more or less constricted portions of the vein. Shoots of this kind are frequently confused with those due to variations in the mineral content. Both types frequently occur in the same deposit.

Irregularities in the contour of the warped surface and the many directions which differential movement may follow along the fracture give rise to great complexity of open space and make the extent and form of the resulting shoots difficult to describe or predict.

A further cause of the limitation of open space in fissures to certain portions of the vein is to be sought in the character of the country rock penetrated by the break.

It frequently happens that fissures penetrate different types of rock. In passing from one rock mass to another, they often alter in character and the open space afforded for deposition may disappear entirely. Thus in the Bachelor vein, near Ouray, Col-

[1] Geological Report on Cornwall, p. 317.
[2] Philips, "Ore-deposits," p. 71.
[3] Beck, "Nature of Ore-deposits," p. 148.

orado, a vein fully five feet wide passes from quartzite into fine carbonaceous shales and after passage into the shales disappears entirely. The movement along the fissure was slight and the shales have entirely absorbed it, adjusting themselves by distortion and plastic flow. The shoot is here limited therefore, by the contact between shales and quartzite, as the quartzite has supported an open space for deposition and the shales have not. Where veins penetrate sediments of alternating massive and shaly character, therefore, shoots may be expected to be either horizontal or to conform in pitch with the layers of rock which afford open space for deposition.[1]

Purington[2] mentions an instance in the San Juan Mountains, Colo., where fissures after passing from andesitic breccia into rhyolite become divided into minute stringers, none of them of sufficient width to mine, and in the aggregate including too much country rock to afford pay ore. Beck[3] mentions an instance where a vein passes from gneiss into quartz-porphyry along its strike and divides into a mass of stringers of small width.

Due to Chemical Effect of Wall Rock.—Where a vein passes from insoluble, unreplaceable rocks into those which are soluble and easily replaced, opportunity is afforded for the expansion of the ore from a vein filling to a flat replacement body. This may extend outward for some distance from the supplying fissure. The production of long linear shoots of ore by the replacement of soluble rock is one of the commonest types encountered where veins intersect rocks of varying lithological character. The fissures are in this case usually small and hardly to be considered as actual veins, though they often occur in great numbers. The mineralization along the fissures themselves is generally slight—often absent entirely—although such shoots do likewise occur where normal veins intersect flat and easily replaced beds.

In the Black Hills the refractory siliceous ores of the Bald

[1] Many other instances, as those cited by Rickerd in Rico and by a great number of other authors, might be quoted, but it is not the writer's intention to exhaust the subject.

[2] "Ore Horizons in the San Juan Mountains," Economic Geol., Vol. I., No. 2, p. 131.

[3] Beck, "Nature of Ore-deposits," Weed's Translation, pp. 119–120.

Mountain district are of this type. Long, narrow and extremely constricted fissures occur here, generally exhibiting a common trend within a limited district, and passing upward through an alternating series of shales, limestones and quartzites. Where they intersect limestones the silica and pyrite with associated gold and silver have replaced the country rock, often to as great a distance as twelve feet. Where many fissures adjoin one another the mineralization arising from one has coalesced with that arising from another and in this way flat masses of ore of great lateral extent have been produced. Such shoots as this of course depend not only on the character of the country rock but upon the location of the supplying fissures. While the latter are often so small as to be with difficulty detected, their grouping has determined the grouping of the resulting shoots. North of Ouray, Colorado, a like state of affairs exists, except that here the shoots occur as lateral enrichments of veins, elsewhere workable.

Due to the Impounding of Mineralizing Solutions.—There seem to be many instances in which bodies of ore are developed, and particularly is this true of the replacement deposits in limestone, by the arrest of active circulation of mineral-laden waters. It is well known that iron-bearing waters passing through pipes produce greater chemical deposition of matter, if allowed to rest than when they circulate rapidly, and the same seems to be true of mineralizing solutions circulating through nature's conduits.

The frequent concentration of ore-bodies beneath impervious cappings seems to afford support to this view. Such instances are seen in the siliceous ores of the Black Hills[1] where vertical fissures pass upward through limestone into impervious shales. The ore-shoots which have been formed by the replacement of limestone are widest just beneath the shales and narrowest in their downward extension, apparently from the arrest and impounding of uprising waters.

In the great Tornado-Mogul shoot the same thing occurs on a larger scale. Here a great phonolite dike forms the west wall of the ore body and not only has the upward progress of waters been prevented by overlying shales but also the lateral expansion

[1] See professional paper 26 U. S. Geol. Sur.

by the porphyry wall. Weed mentions a similar occurrence in the Elkhorn mine in Montana.[1] In Leadville, Colorado, the ores most frequently occur beneath porphyries and it may be that the same cause has been in operation. The intervention of such impervious rocks in the path of mineral waters or any other cause which may operate to impound them, seems to stimulate their chemical activity and increase the extent of area mineralized.

SHOOTS OF VARIATION.

Much more difficult of explanation than the shoots just described are those where the variation in content of valuable mineral occurs within the mass of the deposit itself. In some cases it seems possible to attribute it to some fairly definite cause, but in perhaps the majority of instances it has yet to be satisfactorily explained. The cases in which explanation has been attempted are presented first; the more difficult case (and unfortunately the most important of all) last. Upon this last case it is especially hoped contributions to this discussion will throw some light.

Due to Chemical Effect of Wall Rock.—Where filled fissures penetrate rocks of different types and little or no replacement or alteration of the enclosing rock is noticeable the filling material sometimes contains one valuable mineral or set of minerals in one rock and another valuable mineral or set of minerals in another. Shoots, therefore, correspond in extent with the extent of the favorable wall rock and their shape in longitudinal sections is likewise so determined.

Purington[2] mentions a case in the Smuggler-Union mine in the San Juan Mountains where gold and silver values favor those layers of San Juan andesitic breccia which contain the largest amount of basic minerals. Furthermore, when rhyolite, a much more acidic rock, forms the walls the gold and silver values fall. As the alternating layers of rock are horizontal in position the resulting shoots are likewise horizontal and Purington has given them the name " ore horizons."

It seems very probable here that the basic minerals have

[1] Weed, U. S. Geol. Sur., 22d Ann. Rep., pp. 472–492.
[2] Economic Geology, Vol. I., No. 2, p. 133.

effected a precipitation of the gold and silver from solution or possibly have exerted some catalytic effect on the promotion of the reactions that have produced the gold and silver minerals without themselves entering into the chemical reactions.

Kemp mentions three historic instances, and I cannot do better than quote from his ore-deposits:[1]

". . . in a mine at Schapbach, in the Black Forest, investigated by Sandberger, a vein ran through granite and gneiss. The mica of the granite contained arsenic, copper, cobalt, bismuth and silver, but no lead. The principal ore in this portion was tetrahedrite. The mica of the gneiss contained lead, copper, cobalt, and bismuth, and the vein held galena, chalcopyrite, and a rare mineral, schapbachite, containing bismuth and silver, but probably a mixture of several sulphides. No two ores were common to both parts of the vein. Another well-established foreign illustration is at Klausen, in the Austrian Tyrol. Lead, silver, and zinc occurred in the veins where they cut diorite and slates, but copper where mica schist and felsite formed the walls. In America there are a number of similar cases. At the famous Silver Islet Mine on Lake Superior the vein runs through unaltered flags and shales, and then crosses and faults a large diorite dike. Where the diorite forms the walls, the vein carries native silver and sulphides of lead, nickel, zinc, etc., but where the flags form the walls the vein contains only barren calcite. Along the edges of the estuary Triassic sandstones of the Atlantic border where they adjoin Archean gneiss, a number of veins are found which yield lead minerals, while in the sandstones near the well-known diabase sheets and dikes are others carrying copper ores. It was early remarked by J. D. Whitney that the lead was usually associated with the gneiss, the copper with the diabase."

In his now classical investigations the first of these instances was cited by Sandberger[2] as proof that the ore minerals were leached from the immediately adjoining walls, a view which is now regarded as hardly probable. It seems much more likely that the effect of the wall rock on the solutions in the fissure was the important factor.

When all has been said concerning the influence of wall rock upon the deposition of ores it is still important to recognize that those instances where it is demonstrable are rare. On the other hand instances in which vein fillings are absolutely independent of

[1] Kemp, "Ore Deposits of the United States and Canada," edition of 1903, p. 42.

[2] Sandberger, "Untersuchungen über Erzgänge," Part I.

wall rock are much more numerous than those in which it may be perceived. The character of the mineral waters may then be the variable and determining factor in each case.

Due to Intersecting Veins.—When veins of the same date of formation intersect one another, whether carrying the same sets of minerals or different sets, rich shoots frequently occur at the intersections. In the former cases chemical reactions do not explain the enrichment as no difference in the solutions may be predicated. It seems to me that the enrichment may be due to the arrest of circulation at the point of junction and the consequent added time given the water to deposit and the increased tendency to deposit caused by stagnation or impounding. If the circulations be moving along the fissures in opposite directions a retardation should take place at the junction and this would tend to increase the tendency to deposition. In the Tornado-Mogul Siliceous ore-shoot in the Black Hills the large N. S. ore-body is joined on the east by N. E. S. W. shoots. At the junction rich portions occur higher in gold and silver content than either of the shoots away from the point of intersection.

Where the veins contain different sets of minerals the resulting shoots are apparently due to chemical reactions between the mineral waters. Possibly the most striking instance of this kind on record is that described by Beck.[1] This instance is the Neu-Hoffnung-Flachen vein of the Himmelsfahrt mine, near Freiberg. The vein itself carries lead and barite. The interesting veins carry pyrite, blende and galena. Where they intersect great masses of native silver have been found. From a plan of the vein there given it is shown that the workable shoots occur only at the intersections of cross-veins of which in this instance there are a very large number.

Due to Causes not Fully Understood.—It is significant that the type of shoots which is of greatest importance and of far greater frequency of occurrence than any of the types for which explanations have been suggested should be so little understood and it is for this type of shoot especially that it is hoped this discussion will offer some explanation.

[1] Weed's Translation, pp. 390–391.

Where veins occur in homogeneous rocks which differ little if at all from place to place, where no intersecting fissures are present and where no variation in the size of the vein is responsible for differences in mineral content, the valuable minerals are usually segregated in certain portions of the mineral mass. Such shoots are most frequently fairly well defined and stand at all angles from the vertical. A slight inclination from the vertical is most common, but angles of 45° or even more are often perceptible. A horizontal position is very much less frequent. The material in the veins between the shoots is often difficult to distinguish from the ore carrying greater amounts of valuable mineral, especially in veins of gold and silver. In other cases the metalliferous minerals are readily seen and the barren gangue between them may be easily distinguished. Nearly all gold and silver veins have such shoots. The Lake Superior copper mines show them, the Rand Conglomerates[1] show them, in fact there are few ore-deposits that do not. One can hardly pick up a report or treatise on a mineral district without finding them cited.

Shoots of this kind do not by any means always show regular form. Round masses, extremely intricate bodies, spots and bunches of all sizes are encountered. A definite prevailing trend may often be detected even in masses whose details of form are extremely complex.

For shoots or variation in values of this kind no satisfactory explanation has yet been offered and it seems to me that too few instances of it have been carefully recorded. There are few questions in the entire range of ore-deposits which offer a more attractive or wider field for investigation than this question of the localization of values in ore-bodies; nor are there any problems of more practical significance in the valuation of mineral deposits.

For the final elucidation of the difficult problems involved geologists must look chiefly to facts furnished by the contributions of mining engineers, for their work in the valuation and sampling of mines enables them to present many scientific facts not available to those engaged in strictly scientific work.

J. D. IRVING.

[1] See De Launay, "Mines d'Or du Transvaal," p. 193 and plate opposite.

REVIEWS

The Honorable Peter White. A Biographical Sketch of the Lake Superior Iron Country. By RALPH D. WILLIAMS, Cleveland, Ohio, 1907. Pp. 286; maps and illustrations.

It is rarely that the span of a man's life has compassed the birth and mature development of one of the greatest industries the world has seen, and, yet, that is what has happened in the case of Mr. Peter White of Marquette, Mich., the subject of this biography.

Mr. White is a young man of only seventy-seven summers, but he has seen the district which he calls his home pass from the condition of savagery to that of the highest economic civilization. He has seen the lonely, wild forests transformed into a region teeming with sturdy workmen wielding pick, crowbar and drill, driving huge engines and constructing great power plants, that these erstwhile forests may be compelled to yield that which makes the United States one of the greatest industrial nations of the world. Not only has he seen all this, but he has been an active participant in the great drama. It was he who sent the first shipment of iron ore "down the lakes." It was he, who, personally and alone, established mail connections between the iron district and the outside world. It was he who made possible the building of the railroad from the mines to the lake shore. It was he who, alone, besieged the United States Senate and secured for the city of Marquette the gift of a lighthouse reservation, for the purpose of a city park. In short this wonderful man has been in the forefront of the struggle that has made the Lake Superior region the foremost mineral-producing district in the world. It is not surprising, then, that his biography is intensely interesting from a humanistic standpoint. As a personal biography it is well proportioned, well written, well illustrated and highly diverting. As a story of the frontier it is illuminating. As a picture

of life "in the woods" it is truthful. To one who knows the French Canadian in his humorous earnestness it is extremely entertaining. To him who wishes to gain an insight into the manner of man that accomplishes results, the volume is eminently satisfying. In short, it is a good biography, carefully compiled and well written.

But it is not merely the biography of a man, it is the biography, as well, of a great industry, for the man and the industry are "parts of one parcel." This biography pictures the conditions that prevailed before the discovery of iron ore in the Lake district, and incidentally gives a history of the development of explorations in the region. It describes the discovery of the ore, the hardships of the pioneer miners, and the attempts to smelt the ore near the mines. It narrates the means by which the ore, after painstaking labor, was finally gotten to the lower Lake ports, the methods by which the great carrying trade of the Lakes was developed, and the way in which the formidable rapids of the "Soo" were literally circumnavigated. Incidentally, there are woven into the narrative, sketches of the men who have been instrumental in building up the iron-ore trade, and brief descriptions of the manner in which this has been accomplished.

The stages by which the unbroken wilderness of the "Chippeway land grant" has become the premier mining district in the world are faithfully depicted, and all in a manner that will hold the reader until he has reached the end of the volume.

Best of all, the book, though a romance, is a romance founded on fact. "There is no statement in it that is not the result of patient research. It has seemed best to write it while it was yet possible, for the information which it contains has been secured at first hand. The industrial supremacy of the United States among nations is due wholly to the purity, abundance, cheapness of mining and low rate of transportation of Lake Superior ores. There are living chronicles today of the early development of this region—men, who as boys went into that country to develop it, then an unbroken wilderness—and from their lips the story has been secured. Obviously if not written now it could not, in a little while, be written at all. So vast indeed has been the

progress since that it seems incredible that it should have occurred within the lifetime of one man. Yet Lake Superior, in a commercial sense, is only fifty years old. The beginnings, therefore, of this great iron industry are historically important and are of interest to every citizen in the United States, for there is not a man or woman today living who has not been, directly or indirectly, benefited by the great mineral wealth of the Lake Superior country and the labor of winning it and working it into the arts."[1]

W. S. BAYLEY.

The Granites of Maine. By T. NELSON DALE. With an Introduction by George Otis Smith. Bulletin No. 313 U. S. Geol. Survey. Pp. 202; pl. 14; figs. 39.

In this report we have for the first time an adequate account of the granite quarries of Maine and of the rocks they produce. It is expected that succeeding reports by the same author will discuss in a similar manner the granites of other portions of New England.

Dr. Smith in his introduction calls attention to the fact that the great importance of the granite industry of the State depends largely upon the situation of the quarry sites, which are upon tide water. The magnitude of the industry is indicated by the fact that in one of the tide-water counties the annual product reaches the value of $1,000,000.

The coarse-grained rocks that are commercially classed as granites are scattered through the State in irregular areas, the positions of which are indicated on a map. The rocks are intrusive. They send dykes into the surrounding rocks and in some cases they have produced in these a well-marked contact zone. In other cases the contacts between the intrusive and the intruded rocks are sharp. This difference is accounted for by Smith on the supposition that all the granites are in the form of batholiths. These have been eroded to different depths. Where the "roofs" of the batholiths have been entirely removed, the contacts of the granite masses are sharp. Where erosion has not proceeded so far and some portions of the "roofs" have

[1] From the preface.

been left, the contact between the granite and the roof-rock is characterized by a zone of metamorphism, because the escape of gases and water vapor under normal conditions is concentrated at the upper surface of a buried magma.

All of the granites are believed to belong to the same great period of igneous activity which is placed late in the Silurian or in the early Devonian time.

The main body of the report is an excellent discussion of the subject that it attempts to cover. It contains a well-proportioned and thorough account of the rocks that enter the trade under the name of "granites," and a concise but accurate description of the quarries producing them. Many features of practical importance to the quarryman are treated in a way that cannot but be of great help to him in his quarrying operations, while at the same time they will furnish the economic geologist with definitions that will aid him in describing quarries and quarrying operations elsewhere. Moreover, "the observations on the relations of the bands of knots to flow structure in granite, on the parallelism of banding with sheeting and rift, on the relation of sheeting to the surface of the rock, on the cause of sheeting, and on the spacing and distribution of joints, furnish data of high scientific value, which can be used by the geologist interested in the physics of intrusion."

The method of treatment of the subject is so comprehensive that the report might well be used as a text-book on granite quarrying. The special description of the quarries is introduced by a treatise of 62 pages upon such general topics as the composition and physical properties of granites, flow structure, rift and grain, sheets, joints, headings, faults, shakes, sap, etc., that are of interest to all producers and users of granite, and to all geologists who are interested in the coarse-grained, igneous rocks. The literature, at least such of it as is in English, has been well searched for observations on these topics, and a very full series of references is furnished the reader. When we add that the theories proposed by various writers to explain the origin of the phenomena theoretically known as sheeting, rifting, etc., are weighed and tested by observations in the Maine

quarries and where found wanting are replaced by others that are thought to be better adapted to the conditions found, the thoroughness of the author's work may be appreciated. One of the most interesting observations recorded is that the discoloration known as sap in the Maine granites is not due chiefly to the oxidation of the ferruginous compounds, but mainly to the deposition of limonite by ferruginous surface water.

The Maine "granites" that are at present being quarried fall into six classes as follows: biotite granite, muscovite-biotite granite, hornblende granite, hornblende-biotite granite, quartz monzonite and quartz diorite.

Quartz monzonite is quarried at Sprucehead, Knox Co., and Norridgewock, Somerset Co.; quartz diorite at Hartland, Somerset Co., Bryant Pond, Oxford Co., and at Alfred, York Co.; and hornblende granite in a small way on Mount Desert Island. By far the greater portion of the granite quarried is of the first three types.

The "black granites" comprise gabbros, norites, olivine-norites, an altered diabase porphyry, quartz diorites and quartz-mica diorites. There are at present twelve quarries producing these rocks.

The report concludes with an excellent bibliography of the economic geology of granites and a glossary of the scientific and quarry terms used in the text.

W. S. BAYLEY.

A Study of the Uranium and Vanadium Belts of Southern Colorado. By HERMAN FLECK and WILLIAM G. HALDANE. Report of the Colorado State Bureau of Mines for the Years 1905–6. Pp. 47–115. Denver, 1907.

The carnotite and roscoelite deposits of western Colorado and eastern Utah are so unique, so interesting to economic geologists, and there is so little known of them, that anything appearing upon them, especially if it have the name of scientific inquiry, is eagerly scanned by all those interested in the rarer metals. It thus has happened that the report of Professor Fleck and Haldane, which was announced as in preparation, has been awaited with considerable expectation for the past year.

The title of this work does not give an especially good concept either of the field covered or of the work performed, for to that of the southern region they add a description of the carnotite deposits of Rio Blanco and Routt Counties in northern Colorado, while in southern Colorado they did not visit the roscoelite deposits at Placerville, which are now being worked. The treatment is almost entirely from the chemical standpoint, and the geologic descriptions are meager.

During the early summer of 1905 the authors spent a month in the McIntyre Canon, or Snyderville; Roc Creek; Hydraulic; and Vixen, or Naturita, districts. All four districts lie in the same general region, along either the San Miguel River, or the Rio Dolores in Montrose and San Miguel Counties, and may be reached by wagon road at distances varying from 57 to 87 miles from the railroad at Placerville.

The Indians used the bright yellow carnotite for a pigment and it was known for many years to the early settlers, before it was finally discovered in 1899 to be a new uranium mineral. Since that time many efforts have been made to utilize the deposits commercially, and a short history is given of these attempts. Several plants for concentrating the mineral to a marketable basis have been operated for a short time, but only one, the Dolores Refining Company, is still running.

A partial list of minerals containing uranium and vanadium, with some of the properties of the metals, is given, followed by a discussion of the formula for carnotite. The authors agree with Dr. W. F. Hillebrand that no simple formula can be given from present knowledge, and that the formula derived by Friedl and Cumenge is untenable.

But little attention was given to the geology of the deposits, and they quote Ransome as authority for the statement that the sandstone in which the carnotite is invariably found, is the La Plata. It is probably of Jurassic age.

Under the heading "Ore Deposition" two hypotheses are advanced and considered, as a premise to each of which it is supposed that there were extensive deposits of a highly vanadiferous pitchblende in the rocks from which the La Plata sand-

stone was formed, and "within a reasonable area." They consider that such a supposition is reasonable.

These hypotheses are:

"1. Solution of the values at the original location by action of sulphuric acid, or perhaps acid sulphates arising from decomposition of sulphides, and the passage of such solution finally through a layer of fairly porous sandstone containing a precipitating agent.

"2. The concentration of vanadiferous pitchblende particles by action of water currents and subsequent decomposition."

Uranium and vanadium occur in greatly varying proportions in carnotite from different deposits, the ratio of UO_3 calculated as U_3O_8 to V_2O_5, varying from 1 : 0.16 to 1 : 50, but it is not stated whether there is any visible difference between the minerals showing these widely divergent ratios. This diversity of composition is accounted for by the greater solubility of the alkaline vanadium salts than of the corresponding uranium salts, so that the former would travel further through the rocks than the latter, and they thus account for the vanadium mica, roscoelite, deposits at Placerville, with which little uranium is associated. They find it hard to account for the precipitation of uranium from alkaline solutions and think it was probably carried in sulphuric acid solution from which it would be readily precipitated by the carbonates of lime and iron, which occur as cementing material in the sandstone, the shape of the ore bodies being determined by the impervious shales or portions of the sandstone. In the precipitation by calcium carbonate, they agree with Ransome, whom they quote at some length. They note the fact that pitchblende recently discovered near Golden, Colorado, showed an incrustation similar to carnotite.

In many places the richer deposits of carnotite are in a stratum near the surface, while in a lower one there is a mere staining of the sandstone by the carnotite, which they think was leached from above. However in some places similar stains appear above the deposits. These facts would seem to suggest that whole deposits may have traveled either downward or upward, preferably

the latter, owing to capillarity, which in such dry climates is constantly dragging solutions to the surface. With sundry modifications they follow A. H. Low's published method of analysis, which they quote at length, giving their changes and reasons for making them.

The descriptions of the claims visited seem to be largely a transcript of field notes, with assays for U_3O_8 and V_2O_5 of the specimens collected. From the standpoint of the geologist there is something to be desired in fullness, detail, and exactness.

"Green copper," "vanadate," "copper vanadate," "copper uranate" are mentioned as occurring with the carnotite. It is unfortunate that the mode of occurrence and the means of identifying the two last rare minerals are not given. It is also uncertain whether frequent tests for chromium were made upon the green stains attributed to the first three minerals. Specimens from Placerville, Sinbad Valley, and Routt County, tested in the United States Geological Survey chemical laboratory, were found to be colored by chromium, though specimens of green sandstone from the Rio Dolores near the mouth of La Sal Creek showed neither chromium nor vanadium.

A very large amount of analytical work has been done by the authors, as a list of 97 analyses for uranium and vanadium testifies.

The ore bodies are very irregular in shape and size, as well as in richness and content of uranium and vanadium. They seem to be more or less lenticular masses, but varying from 6 inches to 5 feet, commonly 2–3 feet thick, and of uncertain breadth and length. The Maggie C. claim in the Naturita district seems to have the largest body of ore described, where it is said to extend across the claim, which is presumably the statutory size, 660 by 1,320 feet. A grab sample, which was thought to represent the quality to which the ore might be readily sorted, carried U_3O_8, 2.74 per cent., V_2O_5, 1.46 per cent.

The richness of some of the ores is surprising. Ten sacks of ore from the D. U. No. 6 claim carried 17.5 per cent. U_3O_8, but most of the ores tested carried from 1 to 3 per cent. U_3O_8. The highest percentage found was in a specimen from the Sundown

claim in the McIntyre district. The sample carried 21.88 per cent. U_3O_8 and 8.79 per cent. V_2O_5. 495 tons of ore had been removed for mill operations up to the time of the authors' investigation. The ore can be laid down at a mill on Roc Creek or Rio Dolores for from $5.00 to $7.00 per ton by the owner of a claim. Freight rates on ore to the railroad vary from $20 to $25 per ton. If the ore is to be shipped it must be concentrated, and so far this has been found a very difficult undertaking.

From the minuteness of the particles of the carnotite, and the fact that it coated the grains of the sandstone, it was thought that by causing attrition between the grains the ore might be slimed and then separated from the sand. To do this the ore was placed in a sack and kneaded under water until it gave little or no turbidity after standing a few moments. This process was tried upon ore from two localities, Hydraulic and McIntyre, respectively. From the first ore, which carried 4.5 per cent. U_3O_8, 42.5 per cent. was recovered. From the second which carried 1.5 per cent. U_3O_8, 33.6 per cent. of the uranium value was recovered. From these results they decide that the process is impracticable, though one is struck with the thought that mechanical working might increase the extraction. Separation which depends upon specific gravity does not seem possible, and only chemical processes appear feasible, of which four methods are suggested:

Wet Methods:

1. Acid treatment (leach) and precipitation.
2. Alkaline treatment (leach) and precipitation.

Dry Methods:

3. Volatilization of values by heat and chemical agents.
4. Roasting with materials to change values to soluble form.

Method No. 1.—Carnotite is soluble in any mineral acid, but sulphuric alone is cheap enough to be considered. In use, however, it was found that some of the uranium was reprecipitated in unknown forms which are being studied, and the process could not be profitably conducted on the ore used, which carried 1.3 per cent. U_3O_8. However, no value was given to the V_2O_5 present, of which there was as large or a larger percentage.

Method No. 2.—The Dolores Refining Company use a patented method based upon the solution of the carnotite ores in a warm solution of sodium carbonate. The uranium is precipitated with caustic soda, as sodium uranate, and the vanadium with milk of lime as calcium vanadate. This process gives a concentrate containing 85 per cent. uranium oxide, which sold at the time reported at $2.40 per pound in ton lots. The vanadium was not worked at that time.

Method No. 3 is dismissed as impracticable and *No. 4* has been tried by roasting with salt as a chlorinizer, but was not a success. Wood, coal, limestone and water are present in sufficient quantities and available at fair cost. Methods of radium extraction are discussed, but are not considered practicable. The carnotite contains less radium than some pitchblendes.

Near the close a short account is given of a number of deposits in Rio Blanco and Routt Counties, but strangely no notice is taken of the fossil wood occurring in the Rio Blanco deposits. While the occurrence of the wood in the deposit may be merely a coincidence, the weight given carbonates as precipitants and the fact that on the May Day claim in the McIntyre district a deposit of carnotite 15 inches thick occurs in carbonaceous shale and also that on the Silvey claims rich carnotite deposits occur in a coal seam, though the authors say, without stating a reason, the coal could hardly have been the precipitant, makes the matter of interest at least. In the case of the deposit of carnotite with coal, the authors appear to think that the coal and uranium minerals were deposited at the same time, though no evidence is given to show why such a conclusion is reached.

FRANK L. HESS.

The Lignite of Mississippi. BY CALVIN S. BROWN. Mississippi State Geological Survey. Bulletin No. 3, pp. 71 and map. 1907.

This report presents new and valuable information about a little known resource of the state and commends itself at once to the engineer and the layman. As a reconnaissance report it presents data gathered during three months from some thirty

counties, with prefatory remarks on lignite in general and reference to occurrence and use of deposits in other states.

Lignites are found in the northeast quarter of the state chiefly in the Wilcox and Claiborne formations of Eocene age and to a less degree in the Tuscaloosa and Grand Gulf formations of Cretaceous and Miocene age. The associated beds are unconsolidated sands and clays of varying color and character. Because of a concealing mantle of later beds the lignite is most commonly found in water wells or in gullies and stream beds, though its horizon is locally indicated at the base of hills by springs. In some places burning beds are known.

The lignite occurs at many horizons in lenses of more or less local extent and of varying form. It may grade into the associated clays and differ in ash and sulphur content and in hardness and degree of lignitization within a few feet. The observed thickness of any bed is commonly less than three and very exceptionally more than five feet. At one place it measures from seven and a half to eight feet and at two others exceeds five feet. In localities where other writers report beds fourteen to twenty feet thick Mr. Brown states that he has been unable to verify the measurements.

The Mississippi beds are thought to approximate the quality of similar brown lignites of Texas and North Dakota and to compare favorably even with the black lignites of Colorado, Montana and Wyoming. The basis for the conclusion as presented is a series of forty or more chemical analyses and heat unit determinations made on the air dried material. The samples do not seem as a rule to represent any considerable thickness owing to the fact that few, if any, of the beds are well exposed, and an auger does not work successfully with the methods used. Notes are often lacking as to the thickness of lignite represented by the samples analyzed. Though most of the analyses are on air-dried lignite, additional reports are presented for sealed samples taken at seven localities in duplicate and analyzed in different laboratories. The total moisture of these as determined by W. F. Hand and by S. W. Parr averages about 34 to 48 per

cent., respectively, this poor check perhaps being due to improper mixing and dividing of the samples.

In this connection may be noted the growing belief of coal chemists that close comparison of analyses of air-dried samples may be quite misleading unless the air-drying losses are expressed. This would seem to be especially true in the case of lignites, which contain high percentages of moisture and yield it in varying proportions on air-drying. As a matter of interest the reviewer has referred the heat units determined by Hand and by Parr to "oven dry" coal as a basis. It was found that samples Nos. 43, 48 and 50, of approximately the same ash content, still differ by 400 to 700 B. T. U., those of Mr. Hand being the higher. This suggests a constant error in one of the laboratories. Comparison has also been made of heat units of the North Dakota, Texas and Mississippi lignites on the basis of "coal as received." The North Dakota and Texas values average 7,136, while the samples from Mississippi, as determined by Hand and by Parr, average about 6,655 and 5,315, respectively. These calculations indicate that Mississippi lignites probably have a somewhat lower heat value in the seam than those of North Dakota and Texas.

The possible uses of the lignite, if it can compete in the market with coal, are many. Its energy can be most completely utilized by means of the gas producer and gas engine, though it is not certain that this is the cheapest method of using it. In Mississippi the lignite is thought to be especially available for use in burning clay ware which can be made from closely associated beds. Mr. Brown concludes that the fuel is a resource of commercial value and mentions several localities where its thickness, quality and situation warrant utilization. Future investigators will find the detailed locality notes of the report most valuable.

FRANK W. DE WOLF.

URBANA, ILLINOIS,
March 5, 1908.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

CHARLES H. CLAPP.

METALLIFEROUS DEPOSITS.

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SCIENTIFIC NOTES AND NEWS[1]

IT MAY NOT be clear to all who are interested in the geological work of the Canadian Geological Survey, as to what the exact character of the Canadian organization now is. As recently organized the Canadian Geologists and Government Engineers are grouped in a single, but divided organization. At the head of the entire mining and geological activity is a Minister of Mines, now the Honorable Mr. Templeman. As the actual executive head, under him, comes the Deputy Minister of Mines. This position is now occupied by Mr. Low. There are two distinct branches: the Mines branch and the Geological Survey. The Director of the Mines branch is now Dr. Howell and the Director of the Geological Survey is Mr. Low. Owing to the recent illness of Mr. Low, Mr. R. W. Brock is now acting Director of the Geological Survey. It is uncertain whether Mr. Low's health will permit of his return to active work, in which case Mr. R. W. Brock, now acting director, will undoubtedly be appointed director.

THE U. S. GEOLOGICAL SURVEY has recently lost by resignation Dr. E. C. Sullivan of the Chemical Division, and Mr. F. B. Weeks, geologist and librarian.

MESSRS. A. C. SPENCER and F. L. HESS, of the Geological Survey, in company with T. L. Watson, State Geologist of Virginia, examined some rutile deposits near Tye River, Va., in the middle of March.

FOR A NUMBER OF YEARS the lead and zinc deposits at Joplin, Mo., have been the subject of close examination by geologists of the U. S. Geological Survey. In continuation of this work, which has proved extremely valuable to the mining interests of

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

that region, C. E. Siebenthal spent the winer of 1906 and 1907 in making a survey of the Wyandotte quadrangle for folio publication. This quadrangle contains the southwestern continuation of the Joplin field and lead and zinc are its most important economic deposits. In the summer of 1907 Mr. Siebenthal made a sixty-day reconnaissance into Indian Territory to ascertain the relations of the formations in the Independence quadrangle to those of the Wyandotte and Muskogee quadrangles. The results of this work will appear in "Contributions to Economic Geology" for 1907.

During the past winter Mr. Siebenthal has devoted much of his time to the statistics of production of lead and zinc in the United States. Heretofore, the statistics of production in the Mississippi Valley have been received from the smelters but are now being obtained directly from the producers.

THE DIVISION OF ALASKAN MINERAL RESOURCES having received its usual appropriation of $80,000, the work in Alaska which has been carried on by the U. S. Geological Survey for a number of years will be continued during the coming season. The field operations will begin as soon as the weather will permit. Two parties left Washington the first of March to go in over the ice from Valdez and others will follow after the spring break-up. Thirteen parties will be put in the field, six of these giving their time to geology, two to the investigation of water resources and the others to topography.

The plans for geologic work are as follows:

C. W. WRIGHT will continue his detailed studies of some of the important mining districts of Prince of Wales Island, including the Kasaan Peninsula and Copper Mountain regions.

F. H. MOFFITT, assisted by Adolph Knopf and S. R. Capps, will explore the northern copper belt along the north side of Wrangell Mountains from White River to the Nabesna. Surveying in this region is progressing actively on account of the large amount of capital being invested in railway construction and mine developments in the Copper River region. In view of the inaccessibility of his field, Mr. Moffit had supplies sledded in from Valdez to the Nebesna in February.

DURING THE SUMMER of 1907 the Geological Survey of Vermont, under the direction of Professor G. H. Perkins, state geologist, has been carrying on several lines of investigation. In the Champlain Valley, Dr. Perkins and Mr. G. E. Edson have studied the Lower Cambrian beds which are well exposed from Highgate, through Swanton, St. Albans, Georgia and Burlington in the immediate vicinity of the lake. Many of the layers which heretofore have been supposed to be barren of fossils have, upon more thorough investigation, yielded many specimens of *Olenellus, Ptychoparia, Microdiscus, Hyolithes, Lingullela, Billingsella, Cruziana,* tracks, borings, etc. It is believed that when these collections are carefully studied, a number of forms new to this region will be found. Professor C. H. Hitchcock has been examining the surficial geology of Windsor County and he has also studied the exposed ledges and collected materials for a geological map of that area. Professor C. H. Richardson has explored Orleans County and adjacent areas in the northern part of the state. The results of these investigations will be published in the Sixth Report of the State Geologist which will be issued during the coming season. In addition to the above, Professor T. N. Dale, under the auspices of the United States Geological Survey, has made a thorough study of the granite areas of the state, visiting all worked quarries and taking samples for examination. An abstract of this work will be given in the above Report and the full statement of the results of Professor Dale's study will form a Bulletin of the United States Geological Survey.

THE GEOLOGICAL SURVEY OF MICHIGAN has published recently a series of essays on peat by Professor C. S. Davis. Not only are the distribution and uses of peat in Michigan fully discussed, but also novel and important theories are offered as to the relatively minor importance of sphagnum. This report should be of exceptional interest and value to all who are interested in the subject.

W. P. BLAKE, emeritus professor of geology, University of Arizona, has recently made a second visit to the deposits of

alunogen on the upper Gila River in New Mexico, and has also examined a group of gold-bearing quartz veins which traverse the granite of Cherry Creek bordering the Verde Valley in Yavapai County, Arizona.

PROFESSOR U. S. GRANT will make supplementary investigations of the geology in the Prince William Sound region and W. W. Atwood will study the stratigraphic relations of the coal fields in the Alaska Peninsula.

L. M. PRINDLE will spend the summer in a detailed investigation of the placer deposits and the associated bed rock in the vicinity of Fairbanks, his purpose being to determine so far as possible the genesis and distribution of the gold; and A. G. Maddrin will make a geologic and topographic reconnaissance of Innoka River, a tributary of the lower Yukon, where important discoveries of placer gold were reported in the summer of 1907.

P. S. SMITH, who has been engaged during the past two years in detailed studies in Seward Peninsula, will carry on special investigations of the geologic and economic problems, and E. M. Kindle, who for the last three years has been studying Paleozoic rocks of Alaska, will investigate the terranes of this period in the peninsula and in coöperation with Mr. Smith will attempt to determine the stratigraphic sequence.

THE SUPERVISION of the Alaskan work will continue to be conducted by Alfred H. Brooks, who will be engaged in office work until July. He will then visit some of the parties in southeastern Alaska and later those in the interior.

DAVID T. DAY, of the Geological Survey, will spend the month of April visiting the mid-continent and Gulf Coast oil fields, returning by way of the Illinois and Lima-Indiana oil fields. The purpose of the trip will be to examine the fields and obtain a complete series of the oils for comparative analysis. In May and June Dr. Day will visit the platinum localities in the United States and the oil fields of the west coast. J. P. Dunlop will assist Dr. Day in the collection of samples in the mid-continent field.

L. C. GRATON, of the Geological Survey, returned to Washington in February from Shasta County, California, where, with the assistance of B. S. Butler, three months were spent in completing an investigation of the copper deposits begun the year before. The copper camps of Cananea, Mexico; Jerome, Ariz.; Frisco and Tintic, Utah, and Ely, Nevada, were also visited during the year.

PROFESSOR F. W. CLARKE'S book, "The Data of Geochemistry," which has just been published as Bulletin 330 of the U. S. Geological Survey, will be of great interest to geologists and chemists.

TWO LARGE QUARTO VOLUMES containing all the papers given at the International Geological Congress at Mexico have just appeared.

JAMES H. GARDNER, of the Geological Survey, went to Carthage, Socorro Co., New Mexico, in February to examine and classify certain townships in that vicinity.

WALDEMAR LINDGREN, of the Geological Survey, left Washington March 15 for a six weeks' trip through California, Utah and Nevada to make geological studies and collect statistical data.

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